Technical Description Summary

Shell Exploration & Production Company –Alaska Venture (Shell) is currently proposing to use a remotely operated vehicle (ROV) as another option to the drill bit system in order to implement mudline cellars (MLC) associated with exploratory wells in the Chukchi Sea. The ROV will sit on the sea floor and could use a number of different implements (i.e. excavator bucket, rotating cutter, and/or rock hammer) to mobilize the seafloor sediments. These sediments will then be removed by a pump mounted on the ROV and discharged away from the MLC site. Discharge of MLC cuttings is authorized as discharge 013 (muds, cuttings, and cement at the seafloor) in NPDES Permit No. AKG-28-8100.

The ROV will require an approximate 15 degree ramp to maintain stability while in operation. This requirement will result in larger volumes of sediment to be mobilized than were modeled in the Ocean Discharge Criteria Evaluation for Oil and Gas Exploration Facilities on the Outer Continental Shelf in the Chukchi Sea, Alaska (ODCE) used to support the issuance of NPDES Permit No. AKG-28-8100.

As discussed further, Shell has modeled the impacts of the additional discharge volume resulting from this MLC ROV approach, and compared it to that considered from a drill bit system in the ODCE. The model demonstrates that given the design characteristics of the discharge, the resulting sedimentation shown by the modeled scenarios continue to support a determination of no unreasonable degradation in the ODCE.

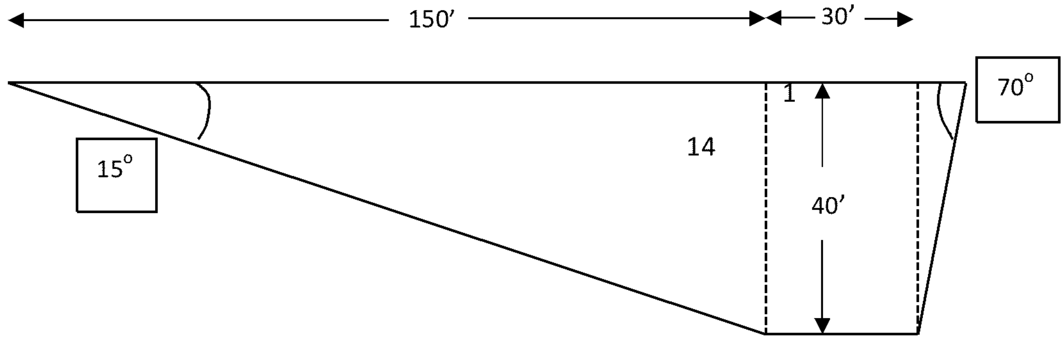
Operations Description Summary

The ROV can be deployed from a marine vessel or a drilling unit. It will be positioned on the sea floor and is capable of executing the MLC through remote control from the vessel or drilling unit deck. The only discharges associated with this activity will be the excavated sediments and rock cuttings. Obviously, the main purpose for the construction of an MLC in this context is to allow for subsequent exploratory drilling for the discovery of hydrocarbons.

The approximate dimensions of the MLC using the MLC ROV system are a 30' x 30' x 40' cellar; a 30' x 15 degree ramp into cellar, with approximate ly 70 degree sides within the MLC as shown in Figure 1. Please note that based on site-specific conditions, the dimensions of the cellar may change with respect to sidewall and ramp angles need ed to maintain the hole integrity, but overall size and volume of sediments needed to be displaced will not change significantly.

Figure 1: Approximate configuration of MLC using MLC ROV system.

Note: Dimensions are not to scale.



The duration of time the MLC ROV system will be used at each drill site also will depend on site-specific conditions, and it is anticipated to take approximately 168 hours (7 days). The estimated volume of cuttings/sediments, including fifty percent (50 %) washout of the ROV excavation, is estimated to be 27,197 barrels (bbls) of material. This results in a cutting mass discharge rate of approximately162 bbls/hour. The maximum discharge volume of cuttings EPA modeled for use in the ODCE was 4,152 barrels.

To compare how the additional volume of cuttings/sediments might affect the surrounding seafloor, Shell conducted a modeling exercise using a dispersion model developed by the Offshore Operators Committee (OOC), a consortium of companies operating in the waters of the Gulf of Mexico. This model predicts the fate of effluents, including drill cuttings, discharged from offshore drilling and production operations (Alam and Brandsma, 2013; Brandsma and Smith, 1999). The OOC model predicts the fate of drilling mud, cuttings, or produced water discharged from a single pipe. This modeling was performed by Fluid Dynamics, LLC, and is provided in Attachment 1.

Comparison to ODCE model evaluations:

<u>Depositional Thickness</u>

The ODCE was informed by a modeling exercise performed by Tetra Tech and provided to the USEPA Region 10 as a technical memo, dated October 23, 2012. Tetra Tech looked at several modeling scenarios that were then used in the ODCE. Below is a reproduction of Table 3.8 from the ODCE that shows the depositional thickness of cuttings as a function of distance away from the discharge point.

Case ID	Discharge Height Above Bottom Depth (m)	Current Speed (m/sec)	Deposition Thickness 250 um Cutting At 1, 3.2, 10, 32, and 100 meters (meters) 1 m	3.2 m	10 m	32 m	100 m
CASE-101	2.0	0.02	158.823	17.681	0.059	0.000	0.000
CASE-102	2.0	0.10	57.879	23.549	4.745	0.105	0.000
CASE-103	2.0	0.30	21.322	10.767	4.299	0.821	0.015
CASE-104	2.0	0.40	16.193	8.400	3.654	0.914	0.040
CASE-105	5.0	0.02	63.014	18.543	1.339	0.001	0.000
CASE-106	5.0	0.10	16.021	7.917	2.952	0.454	0.004
CASE-107	5.0	0.30	5.558	2.995	1.468	0.536	0.077
CASE-108	5.0	0.40	4.190	2.282	1.158	0.471	0.095
CASE-109	20.0	0.02	9.864	4.719	1.588	0.177	0.001
CASE-110	20.0	0.10	2.095	1.141	0.579	0.235	0.047
CASE-111	20.0	0.30	0.705	0.393	0.213	0.108	0.043
CASE-112	20.0	0.40	0.530	0.296	0.162	0.084	0.037
CASE-113	40.0	0.02	3.621	1.878	0.817	0.204	0.009
CASE-114	40.0	0.10	0.746	0.413	0.221	0.106	0.036
CASE-115	40.0	0.30	0.250	0.140	0.077	0.041	0.020
CASE-116	40.0	0.40	0.188	0.105	0.058	0.032	0.016
CASE-117	50.0	0.02	2.610	1.376	0.630	0.185	0.013
CASE-118	50.0	0.10	0.535	0.297	0.160	0.079	0.030
CASE-119	50.0	0.30	0.179	0.100	0.056	0.030	0.015
CASE-120	50.0	0.40	0.134	0.075	0.042	0.023	0.012

Table 3-8. Predicted Solids Deposition for Cuttings Discharge (1,000 bbl, 250 um grain size)

For comparison, the estimated parameters for the discharge from the MLC ROV system is a discharge height above water depth at approximately 1.82 m in a water depth of approximately 42 meters, and a cutting mass rate of approximately 162 bbl/hour. The pump's suction pipe will intake a large volume of sea water to move the cuttings/sediments and were modeled to discharge from a 16.0 inch internal diameter pipe. The pre-dilution discharge rate was therefore estimated to be 13, 529 bbls/hour. This discharge rate is similar to the pumping considered for evacuating the M LC construction in the ODCE. The model was run under t wo conditions of current speed; a mean current speed of 0.7 meters/sec and a maximum current speed of 0.25 meters/sec in the direction of the discharge. In the ODCE, depositional thickness for 250 μm particles at 100 meters from the discharge ranged from 0.00 to 0.095 meters depth for the 20 scenarios modeled. As shown in the table below, depositional thickness of the 250 μm particles for the MLC ROV system fall within this range for the two scenarios modeled.

Senario	Discharge Height Above Bottem Depth (m)	Current Speed (m/sec)	10 m	Depostional Tickness 250 um Cutting At 10, 20, 90, 110 meters (meters) 30 m	90 m	100m
Mean Currents	1.82	0.07	0.378	0.006	0.000	0.000
Max Currents	1.82	0.25	0.016	0.069	0.047	0.034

In addition, the OOC model predicted maximum deposit thickness of all particles at the mean currents is 8.8 meters, which occurs at 10 meters to the east and 10 meters to the north from the discharge location. It decreases to a value of 0.01 meters at a distance approximately 200 meters to the east from the discharge location. The OOC model predicted maximum deposit thickness at the maximum currents is 2.6 meters which occurs at 30 meters to the east and 10 meters to the north from the discharge location. It decreases to a value of 0.01 meters at a distance approximately 500 meters to the east from the discharge location.

Seafloor area affected by discharge

The OOC model shows that the sea floor area affected by solids deposit thickness of 1 cm or larger is approximately a 240 m x 40 m rectangular area (or 0.981 hectares) under mean current conditions. The sea floor areas affected by depositional thickness greater than 5, 3, 1, .0.1, and 0.01 meters are: 0.099, 0.108, 0.118 , 0.336, and 0.981 ha, respectively. The sea floor area affected by solids deposit thickness of 1 cm or greater is approximately a 500 m x 40 m rectangle area (or 2.003 hectare) under maximum current conditions . The sea floor areas affected by depositional thickness larger than 1, .0.1 and 0.01 meters are: 0.270, 0.837, and 2.003 ha, respectively. Additional information and figures showing the aerial extent of the discharge plume are contained in the modeling report provided in Attachment 1.

Table 3-8 from the ODCE shows that most cuttings would settle within 100 meters of the discharge point under all scenarios. Similarly, most particles from the MLC ROV discharge will settle within 100 to 200 meters of the discharge point However, the high er discharge rate from the MLC ROV system does result in a larger predicted area of particles with a thickness of 1 cm or greater on the sea floor. As part of the requirements under NPDES Permit No.: AKG- 28-8100, the permittee must conduct an Environmental Monitoring Program (EMP) to evaluate the short and long-term affects of discharge s authorized by the permit. The influence of the additional drilling cutting on the surrounding sea floor from the MLC ROV system is not expected to result in any long-term affects; and this will be verified as part of EMP plan of study.

Evaluation of ROV excavation system discharge against Ocean Discharge Criteria:

As stated above, the ODCE was developed by USEPA to support the issuance of NPDES Permit No: AKG-28-8100. In order to make a determination of no unreasonable degradation, USEPA must evaluate the discharge based on 10 criteria. Shell believes that the additional volume of cuttings/sediments discharged by the MLC ROV system falls within, and do es not alter, the determinations made for sea floor discharges under the 10 criteria and other factors specified in 40 CFT 123.122(a)-(b) and considered in the ODCE.

Criterion 1. The quantities, composition, and potential for bioaccumulation or persistence of the pollutants to be discharged.

Analysis of this criterion in the ODCE focused on; 1) the total number of estimated wells to be drilled over the 5 year period of the permit, 2) the area of seafloor that would be covered to varying thicknesses by the discharges, and 3) whether or not chemicals in the discharges are persistent in the environment or bioaccumulate.

The total number of wells is not likely to be exceeded by use of an MLC ROV system. There are currently no operators who have utilized coverage under this permit for the first two years of the five year duration. In its analysis, USEPA considered a large (24-42) number of wells and it is highly unlikely that this number will be exceeded in the years remaining prior to permit expiration. As for wells in any one year, the ROV system may allow for preparing drill sites for the following year drilling season.

Depositional thickness and area of seafloor affected by the use of the MLC ROV system was modeled and compared to the modeling EPA used to support the ODCE as described above and in Attachment 1. Similar to the modeling evaluations in the ODCE, most particles discharged settle within 100 meters of the discharge point. Overall area with deposition greater than 1 cm thickness was modeled to be between 0.98 and 2.0 hectares under mean and maximum current scenarios for the Burger J well.

The potential for persistence or bioaccumulation does not change with the increased discharge volumes from the use of the MLC ROV system . Only seafloor sediments and cuttings will be discharged, no additional fluids or muds (barite for example) will be utilized with the MLC ROV system.

Criterion 2. The potential transport of such pollutants by biological, physical, or chemical processes.

EPA determined that drilling discharges associated with short-term exploration operations would have little effect on the environment due to deposition of drilling related materials. The use of the MLC ROV system will not increase the chemical transport of any metals or organics. Only native sediment and cuttings will be discharged, and as the modeling shows they will settle rapidly and accumulate on the sea floor.

Criterion 3. The composition and vulnerability of the biological communities which may be exposed to such pollutants, including the presence of unique species or communities of species, the presence of species identified as endangered or threatened pursuant to the Endangered Species Act, or the presence of those species critical to the structure or function of the ecosystem, such as those important for the food chain.

EPA determined that on the basis of the transient use of the area by the se species, the limited aerial extent of the potential impacts, and the overall mobility of the species, impacts from oil and gas exploration will not cause unreasonable degradation of the marine environment.

There will be no additional water column effects associated with the MLC ROV system discharge that would lead to an exceedance of acute or chronic water quality criteria . Suspended sediments will rapidly settle out of the water and onto the seafloor. With respect to benthic habitat effects, discharges of MLC ROV cuttings/sediments will occur in the same Area of Coverage analyzed in the

ODCE. As stated in the ODCE, there are no demersal fish spawning locations identified in this AOC . The rate of recovery of benthic organisms from sedimentation effects is primarily a function of the depth of discharged material. The depositional depth of cuttings modeled for the MLC ROV discharge falls within the range of depths evaluated in the ODCE. Recovery of the benthic organisms will be studied as part of the EMP. Because there will be no potential for an increase in bioaccumulation or persistence of pollutants, impacts to species that feed on benthic organisms (sea ducks, guillemots, walrus, gray whales) will not increase due to discharge of MLC ROV cuttings/sediments.

With respect to endanger ed species and the associated behavior changes resulting from drilling noise and drilling support activities, Shell has modeled the sound exposure field generated by an MLC ROV system based on surrogate sound source data from underwater excavation equipment. The level of sound is similar to the MLC drilling system evaluated in the ODCE. Shell will verify sound levels generated by the MLC ROV system while in operation in accordance with requirements under the Marine Mammal Protection Act.

Criterion 4. The importance of the receiving water area to the surrounding biological community, including the presence of spawning sites, nursery/forage areas, migratory pathways, or areas necessary for other functions or critical stages in the life cycle of an organism.

EPA determined that sensitive areas and biological communities are generally associated with shallow waters in the near shore environment. The intermittent nature and limited extent of exploratory discharges, combined with the area and depth restrictions established in the permit, will prevent unreasonable degradation of these areas and communities . The MLC ROV system, when utilized, will dig MLCs in the same locations within the Area of Coverage analyzed in the ODCE and operate in water depths analyzed in the ODCE.

Criterion 5. The existence of special aquatic sites including, but not limited to, marine sanctuaries and refuges, parks, national and historic monuments, national seashores, wilderness areas, and coral reefs.

No marine sanctuaries or other special aquatic sites, as defined by 40 CFR 125.122, are in or adjacent to the Chukchi general permit Area of Coverage . This criterion is not impacted by the change in technology to conduct the activity described.

Criterion 6. The potential impacts on human health through direct and indirect pathways.

EPA included several permit requirements to ensure that discharges authorized under the Chukchi general permit would not pose a threat to human health. The discharges from the MLC ROV system will be native sediments and rock cuttings. No additional fluids will be added, and all permit requirements will be maintained. Shell's EMP will evaluate this discharge as part of the plan of study.

Criterion 7. Existing or potential recreational and commercial fishing, including fin-fishing and shell-fishing.

EPA determined that it does not anticipate significant adverse direct or indirect effects resulting from the authorized discharges on subsistence fishing primarily because existing oil and gas leases are greater than 25 miles from any subsistence use area. As stated previously, the MLC ROV system will be used in the same locations in the Area of Coverage that was analyzed in the ODCE.

Criterion 8. Any applicable requirements of an approved Coastal Zone Management Pla n.

The CZMA consistency provisions at 16 U.S.C. 1456(c)(3) and 15 CFR Part 930 no longer apply in Alaska. Accordingly, federal agencies are no longer required to provide Alaska with CZMA consistency determinations.

Criterion 9. Such other factors relating to the effects of the discharge as may be appropriate.

The EPA determined that, with respect to discharges, there will not be disproportionately high or adverse human health related effects on minority or low-income populations residing on the North Slope and near the Area of Coverage. Part of this analysis is the requirement for an EMP to gain additional information that can be used in future permit decisions. The MLC ROV discharges will be evaluated as part of Shell's EMP. This criterion is not impacted by the change in technology to conduct the activity described.

Criterion 10. Marine water quality criteria developed pursuant to CWA section 304(a)(1).

Parameters of concern for effects on water quality in discharges from oil and gas exploration activities include fecal coliform bacteria, metals, oil and grease, temperature, chlorine, turbidity, total suspended solids, and settleable solids, of these only total suspended solids (TSS) is anticipated to be generated through the use of the MLC ROV system, in a similar manner as are generated with the drill bit system. The total suspended solids (TSS) concentration at 100-, 300-, and 1000-m from the discharge location were modeled to be 359, 73, and 12.0 mg/l, respectively under mean current conditions. The total suspended solids (TSS) concentration w as modeled to be at 100-, 300-, and 1000-m from the discharge location are: 162, 45, and 8 mg/l, respectively under maximum current conditions. It is anticipated that these solids will quickly settle out of the water column. There currently is not an effluent limitation on TSS for discharge 013 in NPDES Permit No. AKG-28-8100.

Literature Cited

Alam, M. and Brandsma, M.G. "GUIDO – Graphical User Interface for the OOC Model for Offshore Discharges, User Guide, Version 7.0", April 2013.

Brandsma, M.G. and Smith J.P. "Offshore Operators Committee Mud and Produced Water Discharge Model – Report and Users Guide", December 1999.

Attachment A

DRILL CUTTINGS MODELING FOR MUD LINE CELLAR BY REMOTELY OPERATED VEHICLE (MLC ROV)

DRILL CUTTINGS MODELING FOR MUD LINE CELLAR BY REMOTELY OPERATED VEHICLE (ROV)

BURGER J WELL

LOCATED OFFSHORE CHUKCHI SEA, ALASKA

Prepared for:

Shell Alaska Venture
Anchorage, AK 99503

Prepared by:

3 Elm Street, Suite 2
Maynard, MA 01754
www.fluid-dynamix.com

May 21, 2014

Copyright 2014 by Fluid Dynamix. Company Confidential.

Report No.	Burger_J_SO6
Author(s):	Alam Mohammed Senior Numeric Modeler Fluid Dynamix Boston, Massachusetts
Reviewer(s):	Louis Brzuzy Senior Science Advisor Shell Alaska Venture Anchorage, Alaska USA, 99503
Date:	Wednesday, April 23, 2014
Data Contributor(s):	A. Michael Macrander Science Team Lead Shell Alaska Venture Anchorage, AK 99503 Heather Ptak Environmental Engineer Shell Exploration & Production Anchorage, AK 99503 Ian Lewis Drilling Engineer Shell Exploration & Production Anchorage, AK 99503 Lana Davis Environmental Engineer Shell Exploration & Production Anchorage, AK 99503 Pete Nelson Schlumberger
Data Coordinator(s):	Barbara Bohn Sr Project Manager Olgoonik / Fairweather Anchorage, AK 99503

Copyright 2014 by Fluid Dynamix. Company Confidential.

Executive Summary

The primary goal of this environmental numeric modeling was to simulate the dispersion and deposition of the water based drill cuttings discharges from the prospect well **Burger J** located offshore Chukchi Sea using the Offshore Operators Committee Mud and Produced Water Discharge Model (**OOC Model**). The prospect well Burger J is located in Block 6912 area of Posey. The depth of water is 43.9 meters (m). The dispersion and deposition numeric simulations were performed for one discrete drilling interval to excavate a Mud Line Cellar (**MLC**) using a large subsea Remotely Operated Vehicle (**ROV**). The ROV will use as needed: an excavator bucket, a rotating cutter, or a rock hammer to excavate the MLC. The ROV will sit on the sea floor and use a number of different techniques to mobilize the seafloor drill cuttings sediments. These sediments will then be pumped away via use of a pump mounted on the ROV itself and discharged away from the excavation site. This constitutes discharge described in Permit No.: AKG-28-8100 as discharge 013 (discharges of muds cuttings and cement at the seafloor). The sea floor discharges occur at 2.44 m (or 8 feet) above the sea floor. The estimated volumes of drill cuttings including fifty percent (50 %) washout for the MLC is 27,197.03 bbls. The duration of drilling is 168 hours (or 7 days). This results in a **cuttings mass discharge rate** (effluent) of 161.89 bbls/hour. The estimated volume of the effluent after pre-dilution by sea water for the MLC drilling interval is 2,272,800.00 bbls. This yields into an 84 pre-dilution factor before discharging into the ambient for this MLC drilling interval. The pre-diluted effluent discharge rate is 13,528.57 bbls/hour. The pump's suction pipe will intake a large volume of sea water to move the water based drill cuttings and were modeled to discharge from a **16.0** inch internal diameter pipe.

The OOC model predicted total amount of solids loading on the see floor as a result of the discharge of water based drill cuttings at **the mean currents** are: (i) less than 1 kg/m^2 at a distance of 700 meters from the source, (ii) less than 0.1 kg/m^2 at 2.0 km from the source, and (iii) less than 0.01 kg/m^2 beyond 5.0 km from the source towards the direction of the current.

The sea floor areas affected by solids deposit loading of more than 100-, 10-, 1-, 0.1- and 0.01-kg/m^2 at **the mean currents** are: 0.345, 1.141, 7.006, 59.020, and 550.870 hectares (ha), respectively.

The OOC model predicted maximum deposit thickness at **the mean currents** is 880.3 cm, which occurs at 10 m to the east and 10 m to the north from the discharge location. It decreases to a value of 1 cm at a distance approximately 200 m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of 1 cm or larger is approximately a 240 m x 40 m rectangle area (or 0.981 ha at **the mean currents** as presented in Figure 5-5b. The sea floor areas affected by deposit thickness larger than 500-, 300-, 100-, 10-, and 1-cm are: 0.099, 0.108, 0.118, 0.336, and 0.981 ha, respectively.

The total suspended solids (TSS) concentration at 100-, 300-, and 1000-m from the discharge location are: 359.1, 73.1, and 12.0 mg/l, respectively at **the mean currents**.

The OOC model predicted total amount of solids loading on the sea floor as a result of the discharge of water based drill cuttings at **the maximum currents** are: (i) less than 1 kg/m^2 at a distance 1,500 m from the source, and (ii) less than 0.1 kg/m^2 at 4.5 km from the source.

The sea floor areas affected by solids deposit loading of more than 100-, 10-, 1-, 0.1- and 0.01-kg/m^2 at **the maximum currents** are: 0.913, 2.281, 8.283, 79.367, and 187.690 hectares (ha), respectively.

Copyright 2014 by Fluid Dynamix. Company Confidential.

The OOC model predicted maximum deposit thickness at **the maximum currents** is 260 cm, which occurs at 30 m to the east and 10 m to the north from the discharge location. It decreases to a value of 1 cm at a distance approximately 500 m to the east from the discharge location.

The sea floor area affected by solids deposit thickness of 1 cm or larger is approximately a 500 m x 40 m rectangle area (or 2.003 ha) at **the maximum currents** as presented in Figure 6-5b. The sea floor areas affected by deposit thickness larger than 100-, 10-, and 1-cm are: 0.270, 0.837, and 2.003 ha, respectively.

The total suspended solids (TSS) concentration at 100-, 300-, and 1000-m from the discharge location are: 161.5, 44.9, and 8.2 mg/l, respectively at **the maximum currents**.

Copyright 2014 by Fluid Dynamix. Company Confidential.

TABLE OF CONTENTS

EXECUTIVE SUMMARY II
SECTION 1.0 INTRODUCTION 1
1.1 THE OOC MODEL 3
1.2 SETTLING VELOCITY DISTRIBUTION FOR SOLIDS IN DRILL CUTTINGS AND FLUIDS 4
SECTION 2.0 AMBIENT CHARACTERISTICS 6
2.1 DEPTH OF WATER 6
2.2 TEMPERATURE AND SALINITY 6
2.3 CURRENT SPEED 6
2.4 WINDS SPEED AND WAVE HEIGHT 7
SECTION 3.0 EFFLUENT CHARACTERISTICS 10
3.1 DISCHARGE SCENARIOS 10
3.2 DRILLING INTERVALS, DRILLING DURATIONS, AND EFFLUENT DISCHARGE RATES 10
3.3 DISCHARGE PIPE AND HEIGHT 11
3.4 FALL VELOCITY CLASSES FOR WATER BASED DRILL CUTTINGS 11
3.5 EFFLUENT DENSITIES 12
SECTION 4.0 MODELING DOMAIN 14
SECTION 5.0 DISPERSION AND DEPOSITION MODELING – MEAN CURRENTS 15
5.1 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – MLC 16
SECTION 6.0 DISPERSION AND DEPOSITION MODELING – MAXIMUM CURRENTS 26
6.1 MODEL RESULTS FOR SEA FLOOR DISCHARGE SCENARIO – MLC 27
SECTION 7.0 SENSITIVITY ANALYSIS 37
SECTION 8.0 SUMMARY AND CONCLUSION 40
SECTION 9.0 REFERENCES 42

Copyright 2014 by Fluid Dynamix. Company Confidential.

TABLE OF FIGURES

Figure 1-1: Location of the Burger Field 2
Figure 1-2: Conceptual Vertical Section of the MLC Profile....2
Figure 2-1: Ambient temperature for open water season, Burger Field, Chukchi Sea.... 7
Figure 2-2: Ambient salinity for open water season, Burger Field, Chukchi Sea 8
Figure 2-3: Wind speed for open water season, Burger Field, Chukchi Sea....9
Figure 2-4: Wave height for open water season, Burger Field, Chukchi Sea....9
Figure 4-1: Modeling domain for the prospect well Burger J 14
Figure 5-1: Trajectory of the discharge plume, Burger J, Drilling Interval 01 - MLC....17
Figure 5-2: Shape and width of the discharge plume, Burger J, Drilling Interval 01 - MLC 18
Figure 5-3: Total suspended solids concentrations in water column, Burger J, Drilling Interval 01 19
Figure 5-4: Amount of deposition of the solids on the seabed, Burger J, Drilling Interval 01....20
Figure 5-5a: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01....22
Figure 5-5b: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01....23
Figure 5-6: Sea floor area affected by solids thickness distribution, Burger J....24
Figure 6-1: Trajectory of the discharge plume, Burger J, Drilling Interval 01 28
Figure 6-2: Shape and width of the discharge plume, Burger J, Drilling Interval 01 29
Figure 6-3: Total suspended solids concentrations in water column, Burger J, Drilling Interval 01 30
Figure 6-4: Amount of deposition of the solids on the seabed, Burger J, Drilling Interval 01....31
Figure 6-5a: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01....33
Figure 6-5b: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01....34
Figure 6-6: Sea floor area affected by solids thickness distribution, Burger J....35

Copyright 2014 by Fluid Dynamix. Company Confidential.

TABLE OF TABLES

Table 1-1: Location of the Prospect Well Burger J....2
Table 1-2: Drilling Operation for Burger J....3
Table 1-3: Fall Velocity Classes for Water Based Mud Cuttings (Brandsma and Smith, 1999)....5
Table 1-4: Fall Velocities for Different Sediment Particle Size and Classes (Keith Dyer, 1986)....5
Table 2-1: Ambient Water Characteristics for the Burger Field, for the planned drilling period....6
Table 3-1: Drilling Operation for Burger J....11
Table 3-2: Fall Velocity Classes and Volume Fractions for Water Based Drill Cuttings, Burger J....12
Table 3-3: Computations of Effluent Bulk Density and Solids Volume Fractions for Burger J....13
Table 5-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger J....15
Table 5-2: Summary Model Results - Sea Floor Discharges at Mean Currents, Burger J....25
Table 6-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger J....26
Table 6-2: Summary Model Results - Sea Floor Discharges at Maximum Currents, Burger J....36
Table 7-1: Mean and Maximum Currents Speed for the Burger Field, for July through October....37
Table 7-2: The OOC Model Predictions at Mean and Maximum Currents Speed, Burger J....38
Table 7-3: The OOC Model Predicted Drill Cutting Deposition Thickness for 1000 Barrel Discharge at Mean Currents Speed, Burger J....38
Table 7-4: The OOC Model Predicted Drill Cutting Deposition Thickness for 1000 Barrel Discharge at Maximum Currents Speed, Burger J....39

Copyright 2014 by Fluid Dynamix. Company Confidential.

SECTION 1.0 I NTRODUCTION

The numeric simulations for the water based drill cuttings discharges from the excavation of a Mud Line Cellar (**MLC**) using a subsea Remotely Operated Vehicle (**ROV**) for the prospect well **Burger J** located offshore Chukchi Sea was conducted using the Offshore Operators Committee Mud and Produced Water Discharge Model (**OOC Model**). The location of the well Burger J, within the Burger Field offshore the Chukchi Sea is presented in **Figure 1-1**. It's located in Block 6912 of area Posey. The coordinates: easting-northing and latitude-longitude are presented in **Table 1-1**. The depth of water is 43.9 meters (m).

The dispersion and deposition numeric simulations were performed for one discrete drilling interval to excavate an **MLC** using a subsea **ROV**. The ROV will use as needed: an excavator bucket, a rotating cutter, or a rock hammer to excavate the MLC. The ROV will sit on the sea floor and use a number of different techniques to mobilize the seafloor drill cuttings sediments. These sediments will then be pumped away via use of a pump mounted on the ROV itself and discharged away from the excavation site. This constitutes a sea floor discharge of **Type D013**. The sea floor discharges occur at 2.44 m (or 8 feet) above the sea floor. The estimated volumes of drill cuttings including fifty percent (50 %) washout for the MLC is 27,197.03 bbls. The duration of drilling is 168 hours (or 7 days). This results in a **cuttings mass discharge rate** (effluent) of 161.89 bbls/hour. The estimated volume of the effluent after pre-dilution by sea water for the MLC drilling interval is 2,272,800.00 bbls. This yields into an 84 pre-dilution factor before discharging into the ambient for this MLC drilling interval. The pre-diluted effluent discharge rate is 13,528.57 bbls/hour. The pump's suction pipe will intake a large volume of sea water to move the water based drill cuttings and were modeled to discharge from a **16.0** inch internal diameter pipe.

The dispersion and deposition numeric simulations were performed for the sea floor discharge scenario for two sets of currents speed: mean currents and maximum currents as listed below. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed.

- **Discharge Scenario 1**: **Sea Floor Discharges (D013) at Mean Currents**
  Water based drill cuttings discharges prior to the installation of the riser near the sea floor

- **Discharge Scenario 2: Sea Floor Discharges (D013) at Maximum Currents**
  Water based drill cuttings discharges prior to the installation of the riser near the sea floor

The ROV will require an approximate 15° ramp to maintain stability. This means that the volume of sea floor cuttings for the ramp may be larger than the volume of sea floor cuttings for the MLC itself. The conceptual design dimensions for the MLC excavation are approximately: 30-foot long x 30-foot wide x 40-foot deep cellar; 30-foot wide and 15 degree (from horizontal) ramp descending from the seafloor to the bottom of the cellar; and a 70 degree (from horizontal) side within the cellar. Actual dimensions of the MLC may differ, but volumes of cuttings will be approximately equivalent. **Figure 1-2** (not to scale) presents the conceptual vertical section of the MLC profile.

Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 1-1: Location of the Burger Field
Prospect Well: Burger J

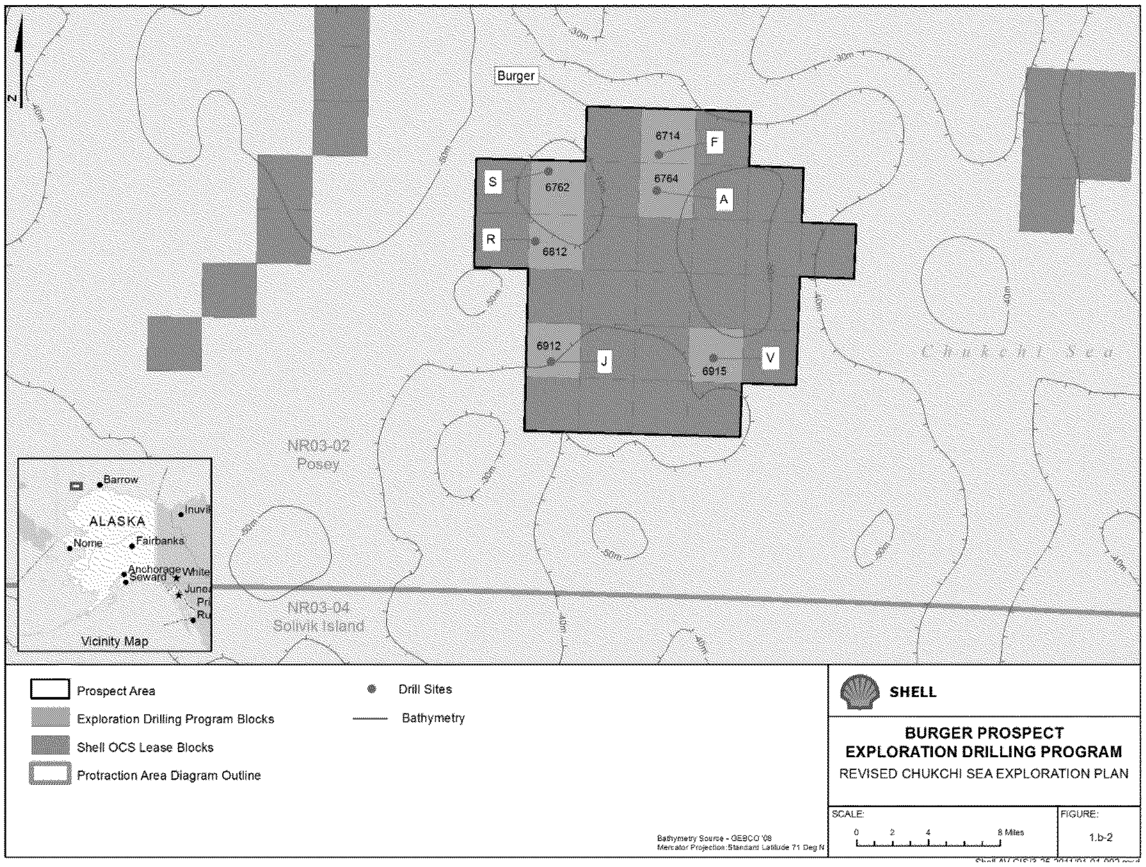
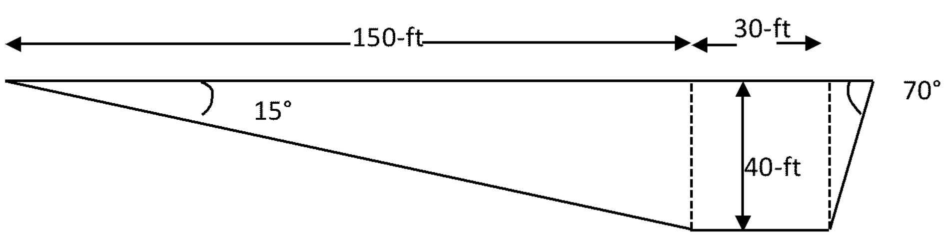


Table 1-1: Location of the Prospect Well Burger J

Prospect Well	Area	Block	Coordinates				Water Depth (m)
			Easting (m)	Northing (m)	Latitude	Longitude	
Burger J	Posey	6912	555,036.01	7,897,424.42	N71° 10' 24.03"	W163° 28' 18.52"	43.9

Figure 1-2: Conceptual Vertical Section of the MLC Profile



Copyright 2014 by Fluid Dynamix. Company Confidential.

Table 1-2 presents the detailed drilling operations and effluent data for the MLC. This table presents the following data: discharge scenarios, drilling intervals, duration of drilling, footage drilled, volume of total water based drill cuttings including washout, volume of seawater added, volume of total pre-diluted effluent, and the effluent discharge rates. The estimated volumes of drill cuttings including fifty percent (50 %) washout for the MLC is 27,197.03 bbls. The duration of drilling is 168 hours (or 7 days). This results in a **cuttings mass discharge rate** (effluent) of 161.89 bbls/hour. The estimated volume of the effluent after pre-dilution for the MLC drilling interval is 2,272,800.00 bbls. The pre-diluted effluent discharge rate is 13,528.57 bbls/hour.

Table 1-2: Drilling Operation for Burger J
DISCHARGE SCENARIOS, DRILLING INTERVALS, VOLUMES OF DRILL CUTTINGS, AND EFFLUENT DISCHARGE RATES

Discharge Scenario	Drilling Intervals	Durations of Drilling (Pumping)	Footage Drilled	Cuttings Volume: 15° Ramp	Cuttings Volume: Cellar	Cuttings Volume: 70° Side	Total Water Based Drill Cuttings including 50% Washout[1]	Effluent Discharge Rate	Seawater Added to Effluent	Total Pre-diluted Effluent (water based drill cuttings + drilling fluids + seawater)	Pre-diluted Effluent Discharge Rate
		(Hours)	(feet)	(bbls)	(bbls)	(bbls)	(bbls)	(bbls/hour)	(bbls)	(bbls)	(bbls/hour)
Sea Floor	**CML**	168.00	40.00	16,029.69	6,411.87	1,549.54	27,197.03	161.89	2,245,603	2,272,800	13,528.57

Note: 1 - 50% washout for Cellar only

1.1 THE OOC MODEL

The Offshore Operators Committee (OOC), a consortium of companies operating in the waters of the Gulf of Mexico, sponsored development of a model to predict the fate of effluents discharged offshore (Alam and Brandsma 2013; Brandsma and Smith, 1999). The OOC model predicts the fate of drilling mud, cuttings, or produced water discharged from a single pipe. Up to 12 classes of particulates may be contained in the effluent. Particulates may be solids or oil droplets. The model predicts the concentrations of particulates and liquid effluents in the water column and the deposition of solid particles on the sea floor. There are no restrictions on the nature of the receiving environment simulated by the OOC model. Bathymetry may be variable or constant depth. Currents and hydrography may change spatially and temporally. Sea state may change temporally. The model couples an integral plume model of initial dilution and dynamic spreading with a far-field cloud-tracking model.

Copyright 2014 by Fluid Dynamix. Company Confidential.

The OOC model has been validated against laboratory and field data (O'Reilly et al., 1989; Smith et al, 1994; and Smith et al., 2004). The OOC model is maintained with the aid of an automated validation system. The validation system produces an HTML report documenting the results of simulating 681 experiments in twenty-five laboratory studies and four field studies (Brandsma, 2004), including a field study of cuttings deposition on the sea floor. The model has been used by several major oil companies around the globe, universities, MMS, and EPA. The model has been applied to offshore Brazil, Gulf of Mexico, Nigeria, North Sea, and Pacific Ocean.

The Graphical User Interface Discharge Offshore (GUIDO), version 7.3 software (Alam and Brandsma, 2013) for the OOC model performs pre- and post-processing for the FORTRAN based OOC model. It allows the user to prepare inputs in convenient systems of units, checks and, if necessary, adjusts inputs for consistency and submits the inputs for execution by the OOC model, in interactive or batch mode.

1.2 Settling Velocity Distribution for Solids in Drill Cuttings and Fluids

Solids in drilling discharges have a range of particle sizes (Brandsma and Smith, 1999). As a result, the settling behavior of the effluent solids is described by a distribution of settling velocities rather than a single settling velocity. The Report and User Guide (Brandsma and Smith, 1999) of the OOC Model presents examples of solids fall velocity data sets for water-based mud, water-based mud cuttings, and oil-based mud cuttings. The Report and User Guide states that these data sets can be used for modeling studies in cases where no site specific data are available on the fall velocity distribution of the effluent solids.

The dispersion and deposition numeric simulations of the water based drill cuttings discharges for the sea floor e discharge scenario was performed using the fall velocity classes for water based mud cuttings presented in the OOC model Report and User Guide (Brandsma and Smith, 1999) for the MLC drilling interval at prospect well Burger J. The volume fractions of the fall velocity classes were adjusted for the effluent based on the actual volume of the total cuttings solids present in the volumes of the total effluent. The fall velocity classes for water based mud cuttings from the Report and User Guide is presented in **Table 1-3**. The actual value of the density for the solids was used in the numeric simulation.

The fall velocities for different sediment particle sizes and classes are presented in **Table 1-4** (Keith Dyer, 1986).

The ambient and effluent characteristics used in the OOC models for the Burger J well are described in detailed in **Sections 2** and **3**. The modeling domain is described in **Section 4**. The modeling results are described in details in **Sections 5 and 6. Section 7** describes the sensitivity analysis**. Section 8** presents the summary and conclusion. **Section 9** lists the references cited in this Technical Report.

Copyright 2014 by Fluid Dynamix. Company Confidential.

Table 1-3: Fall Velocity Classes for Water Based Mud Cuttings (Brandsma and Smith, 1999)

	Density		Fall Velocity	
Class	(g/cc)	Volume Fraction	(feet/s)	(cm/s)
1	2.65	0.04272	0.000004430	0.0001350264
2	2.65	0.03204	0.000055300	0.0016855440
3	2.65	0.03738	0.000716000	0.0218236800
4	2.65	0.01602	0.007638000	0.2328062400
5	2.65	0.01068	0.047480000	1.4471904000
6	2.65	0.09612	0.131600000	4.0111680000
7	2.65	0.08544	0.321400000	9.7962720000
8	2.65	0.08010	0.443500000	13.5178800000
9	2.65	0.13350	0.852200000	25.9750560000

Table 1-4: Fall Velocities for Different Sediment Particle Size and Classes (Keith Dyer, 1986)

Sediment Size Class	Particle Size (mm)	Fall Velocity (cm/s)
		Keith Dyer (1986)
Chunks	> 2.0	65
Sand	0.062 - 2.0	32
Coarse Silt	0.016 - 0.062	0.32
Fine Silt	0.004 - 0.016	0.027
Clay	< 0.004	< 0.01

Copyright 2014 by Fluid Dynamix. Company Confidential.

SECTION 2.0 AMBIENT CHARACTERISTICS

The OOC model was used for the numeric simulations of the dispersion and deposition of the water based drill cuttings discharges from the excavation of the MLC for the prospect well **Burger J** located offshore Chukchi Sea. The required model input data for the ambient conditions are described in this Section.

2.1 DEPTH OF WATER

The ambient water characteristics data set presented in **Table 2-1** for the planned drilling period was used for the dispersion and deposition numeric simulations of the water based drill cuttings, discharges using the OOC model for the sea floor discharge scenarios. The ambient water depth at the Burger J well site is 43.9 m. The planned drilling period is within the open water season of July thru October.

2. 2 TEMPERATURE AND SALINITY

The stratification of the ambient temperature and salinity for the open water season is presented in **Figures 2-1** and **2-2**, respectively. The temperature of the ambient water varies from 4 degrees Celsius (°C) at the surface stratum to - 0.5 °C at the bottom stratum, with a significant stratification occurring at 15 m depth. The salinity of the ambient water varies from 30 Practical Salinity Scale Unit (psu) at the surface stratum to 32 psu at the bottom stratum.

Table 2-1: Ambient Water Characteristics for the Burger Field, for the planned drilling period

Water depth	Temperature	Salinity	Mean Current Speed	Maximum Current Speed	Current Direction
m	°C	psu	cm/s	cm/s	
0	4	30	7	25	to the East
15	3.5	30.5	7	25	to the East
20	-0.3	31.5	7	25	to the East
43.9 - 45.7	-0.5	32	7	25	to the East

2.3 CURRENT SPEED

The report "PHYSICAL OCEANOGRAPHIC MEASUREMENTS IN THE KLONDIKE AND BURGER SURVEY AREAS OF THE CHUKCHI SEA: 2008 AND 2009" (Figures 2 and 3, Weingartner and Danielson, 2010) for the year 2008 states the following: Mean current speeds within the Herald and Barrow Canyons are swift (25 cm/s), more moderate in the Central Channel (10 cm/s), and generally <5 cm/s elsewhere. The prospect well Burger J is located in 71° N and 163° W. It can be seen from Figure 3 (Weingartner and Danielson, 2010) that the mean flow vectors (blue arrows) in the vicinity of 71° N and 163° W are approximately in the range of 3 cm/s to 10 cm/s.

Therefore, the current speed of 7 cm/sec is used in the model as the average value. The current speed of 25 cm/sec is used as the maximum value in the OOC model. The currents turn eastward to enter the Barrow Canyon at 71° N (Ref: Page 4, Physical oceanographic measurements in the Klondike and Burger

Copyright 2014 by Fluid Dynamix. Company Confidential.

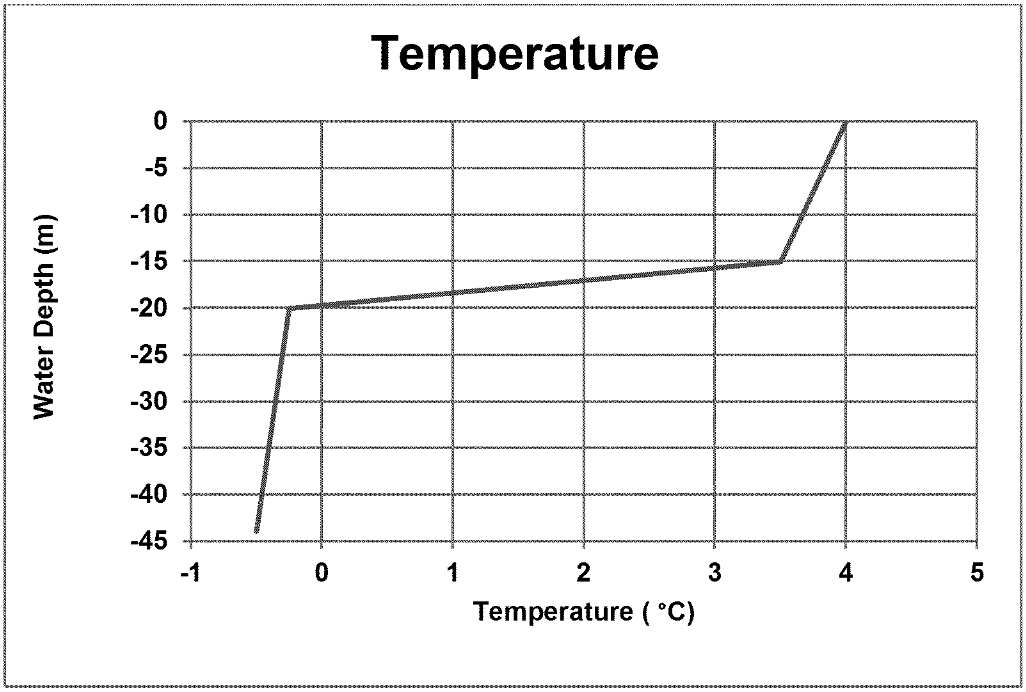
prospects of the Chukchi Sea: 2008 and 2009). The current speed is distributed uniformly with the depth with a prevailing direction of flow to the east for the planned drilling period in the OOC model.

2.4 Winds Speed and Wave Height

The wind speed during the open water season steadily increases from July through October as presented in **Figure 2-3**. The approximate values for the 50-percentile rank wind speeds for July, August, September, and October are 6.8, 7.8, 9.5, and 10.25 m/s, respectively. The tentative drilling period for Burger J is mid-August to mid-September. The average value for 50-percentile rank wind speeds for the month of August and September i.e., 8.65 m/s was used for the Burger J well.

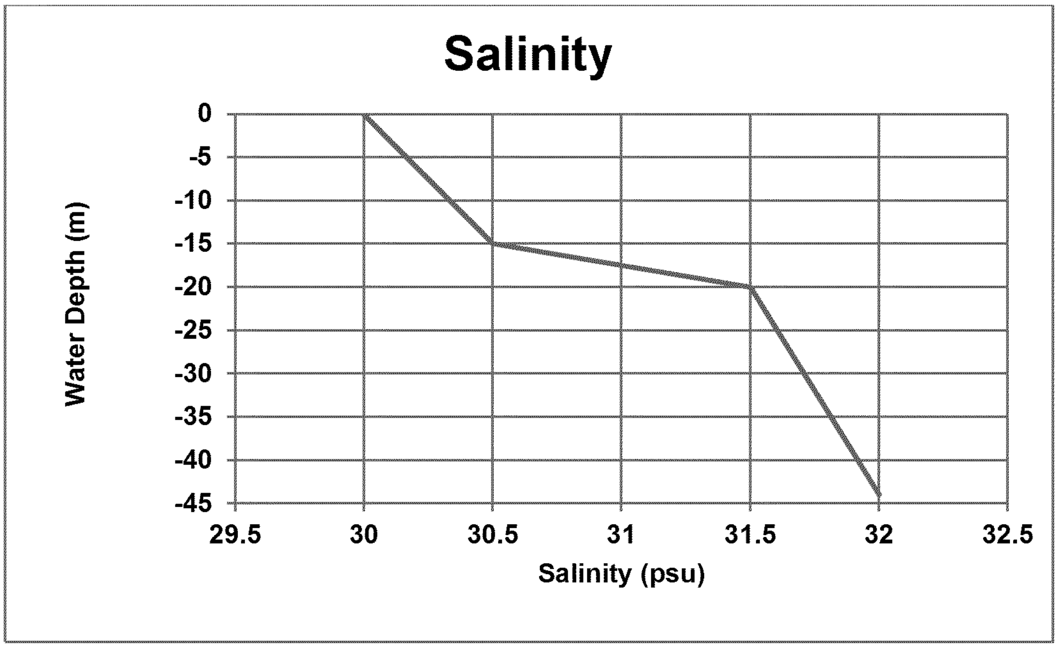
The wave height during the open water season also steadily increases from July through October as presented in **Figure 2-4**. The approximate values for the 50-percentile rank wave heights for July, August, September, and October are 1.2, 1.4, 1.8, and 1.9 m, respectively. The average value for 50-percentile rank wave height for the month of August and September i.e., 1.6 m was used for the Burger J well.

Figure 2-1: Ambient temperature for open water season, Burger Field, Chukchi Sea



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 2-2: Ambient salinity for open water season, Burger Field, Chukchi Sea



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 2-3: Wind speed for open water season, Burger Field, Chukchi Sea

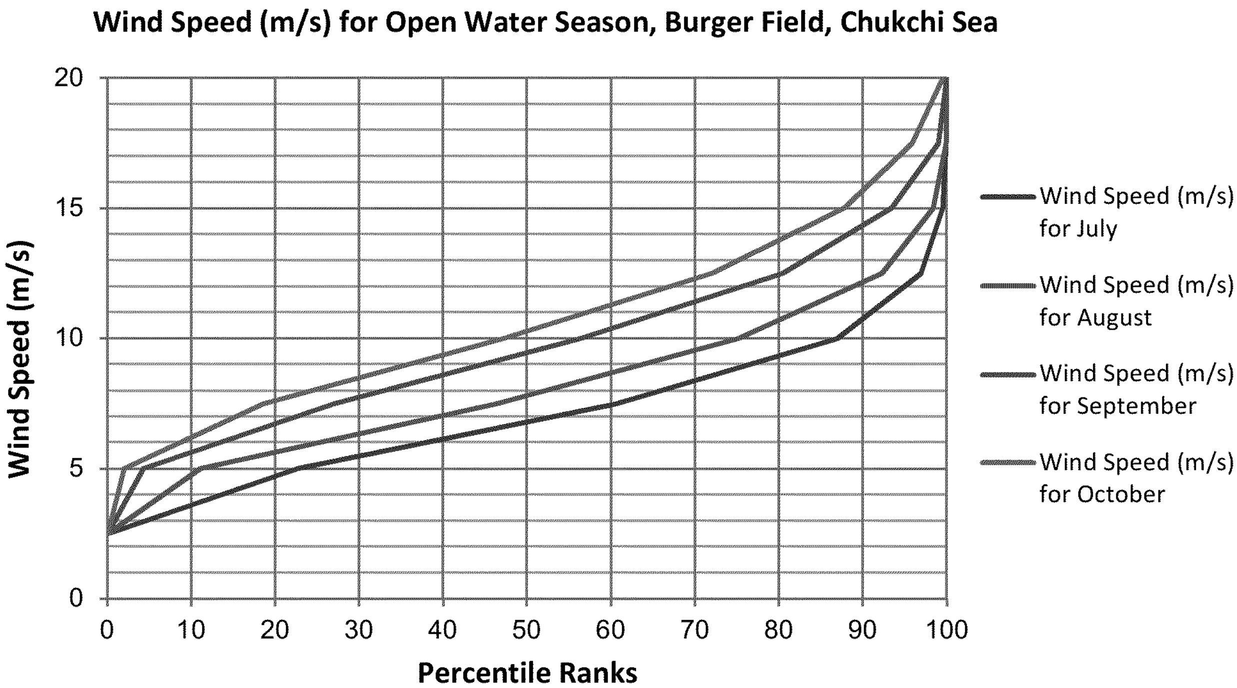
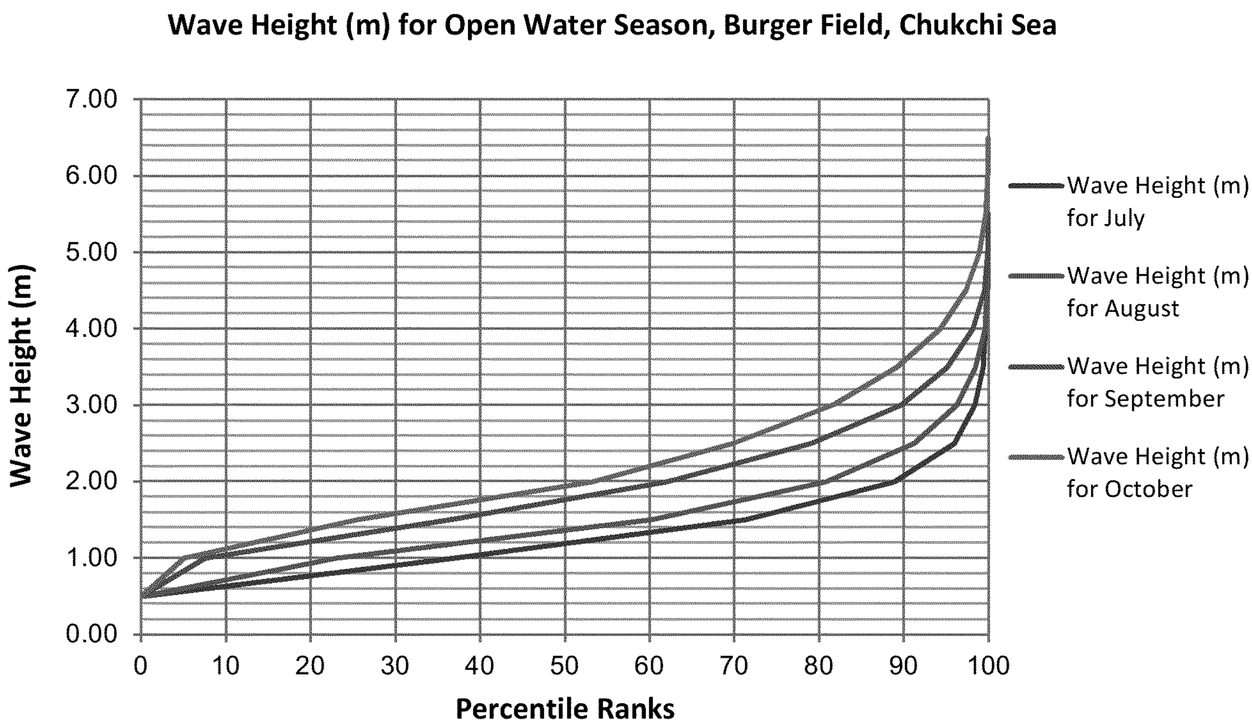


Figure 2-4: Wave height for open water season, Burger Field, Chukchi Sea



Copyright 2014 by Fluid Dynamix. Company Confidential.

SECTION 3.0 EFFLUENT CHARACTERISTICS

The OOC model was used for the numeric simulations of the dispersion and deposition of the water based drill cuttings discharges from the excavation of the MLC for the prospect well **Burger J** located offshore Chukchi Sea. The required model input data for the effluent are described in this Section.

3.1 DISCHARGE SCENARIOS

The dispersion and deposition numeric simulations were performed for the sea floor discharge scenario for two sets of currents speed: mean currents and maximum currents as listed below. This provides a sensitivity analysis of the numeric model results to the model input parameter: currents speed.

- **Discharge Scenario 1**: **Sea Floor Discharges (D013) at Mean Currents**
  Water based drill cuttings discharges prior to the installation of the riser near the sea floor

- **Discharge Scenario 2: Sea Floor Discharges (D013) at Maximum Currents**
  Water based drill cuttings discharges prior to the installation of the riser near the sea floor

3.2 DRILLING INTERVALS, DRILLING DURATIONS, AND EFFLUENT DISCHARGE RATES

The drilling operations for the excavation of a Mud Cellar Line (**MLC**) for the Burger J well would be conducted using a large subsea Remotely Operated Vehicle (**ROV**). The ROV will use: an excavator bucket, a rotating cutter, and a rock hammer to excavate the MLC. The ROV will sit on the sea floor and use a number of different techniques to mobilize the seafloor drill cuttings sediments. These sediments will then be pumped away via use of a pump mounted on the ROV itself and discharged away from the excavation site. This constitutes a sea floor discharge of **Type D013**. The sea floor discharges occur at 2.44 m (or 8 feet) above the sea floor. The estimated volumes of drill cuttings including fifty percent (50 %) washout for the MLC is 27,197.03 bbls. The duration of drilling is 168 hours (or 7 days). This results in a **cuttings mass discharge rate** (effluent) of 161.89 bbls/hour. The estimated volume of the effluent after pre-dilution by sea water for the MLC drilling interval is 2,272,800.00 bbls. This yields into an 84 pre-dilution factor before discharging into the ambient for this MLC drilling interval. The pre-diluted effluent discharge rate is 13,528.57 bbls/hour. The pump's suction pipe will intake a large volume of sea water to move the water based drill cuttings and were modeled to discharge from a **16.0** inch internal diameter pipe.

The effluent characteristics from the drilling operations are presented in details in **Table 3-1** for the MLC. **Table 3-1** presents the detailed drilling operations and effluent data for the MLC. This table presents the following data: discharge scenarios, drilling intervals, duration of drilling, footage drilled, volume of total water based drill cuttings including washout, volume of seawater added, volume of total pre-diluted effluent, and the effluent discharge rates. The estimated volumes of drill cuttings including fifty percent (50 %) washout for the MLC is 27,197.03 bbls. The duration of drilling is 168 hours (or 7 days). This results in a cutting mass discharge rate of 166.88 bbls/hr. The estimated volume of the effluent after pre-dilution for the MLC drilling interval is 2,272,800.00 bbls. The effluent discharge rate is 13,528.57 bbls/hour.

Copyright 2014 by Fluid Dynamix. Company Confidential.

Table 3-1: Drilling Operation for Burger J
DISCHARGE SCENARIOS, DRILLING INTERVALS, DURATIONS OF DRILLING AND EFFLUENT DISCHARGE RATES

Discharge Scenario	Drilling Intervals	Durations of Drilling (Pumping)	Footage Drilled	Cuttings Volume: 15° Ramp	Cuttings Volume: Cellar	Cuttings Volume: 70° Side	Total Water Based Drill Cuttings including 50% Washout[1]	Effluent Discharge Rate	Seawater Added to Effluent	Total Pre-diluted Effluent (water based drill cuttings + drilling fluids + seawater)	Pre-diluted Effluent Discharge Rate
		(Hours)	(feet)	(bbls)	(bbls)	(bbls)	(bbls)	(bbls/hour)	(bbls)	(bbls)	(bbls/hour)
Sea Floor	**CML**	168.00	40.00	16,029.69	6,411.87	1,549.54	27,197.03	161.89	2,245,603	2,272,800	13,528.57

Note: 1 - 50% washout for Cellar only

3.3 DISCHARGE PIPE AND HEIGHT

The sea floor discharges occur at 2.44 m (or 8 feet) above the sea floor at a rate of **13,529 bbls/hr**. The pump's suction pipe will intake a large volume of sea water to move the water based drill cuttings and will discharge from an approximately **16.0** inch internal diameter discharge pipe.

3.4 FALL VELOCITY CLASSES FOR WATER BASED DRILL CUTTINGS

The dispersion and deposition numeric simulations of the water based drill cuttings for the sea floor discharge scenarios were performed using the fall velocity classes for water based mud cuttings presented in the OOC model Report and User Guide (Brandsma and Smith, 1999) for the prospect well Burger J. The volume fractions of the fall velocity classes were adjusted for the effluent classes based on the actual volume of the total cuttings solids present in the effluent. The fall velocity classes and volume fractions for water based drill cuttings used for the Burger J well is presented in **Table 3-2**. The solids density is 2.65 g/cc.

Copyright 2014 by Fluid Dynamix. Company Confidential.

Table 3-2: Fall Velocity Classes and Volume Fractions for Water Based Drill Cuttings, Burger J

Well ID	Sediment Class in Drill Cuttings	Solids Density	Estimated Particle Diameter	Fall Velocity	Volume Fractions
		(g/cc)	micro meter (µm)	(cm/s)	For Drilling Interval - MLC
Burger J	1	2.65	1	0.00	0.0009573
	2		4	0.00	0.0007180
	3		15	0.02	0.0008376
	4		50	0.23	0.0003590
	5		125	1.45	0.0002393
	6		250	4.01	0.0021539
	7		500	9.80	0.0019146
	8		1000	13.52	0.0017949
	9		3600	25.98	0.0029916

3.5 Effluent Densities

The sea water density was computed using the Equation of State presented by Crowley (Crowley, 1986). The computations for the effluent bulk density and the solids volume fractions for water based drill cuttings and drilling fluids for the Burger J prospect well are presented in **Table 3-3**.

Density of sea water at the surface = 1,023.80 kg/m^3.
Density of sea water at the bottom = 1,025.77 kg/m^3
Density of drill cuttings = 2,650.00 kg/m^3.

Copyright 2014 by Fluid Dynamix. Company Confidential.

Table 3-3: Computations of Effluent Bulk Density and Solids Volume Fractions for Burger J

Drilling Interval	Drilling Fluids				Total Cuttings Solids				Sea Water				Computation of Density of Effluent (Bulk Density)				Volume of Solids in Effluent	Volume Fraction of Solids in Effluent
	Density	Volume		Mass	Density	Volume		Mass	Density	Volume		Mass	Total Mass	Total Volume	Bulk Density			
	kg/m³	bbls	m³	kg	kg/m³	bbls	m³	kg	kg/m³	bbls	m³	kg	kg	m³	kg/m³	lbs/gal	m³	
1	1,076.13	-	-	-	2,650	27,197	4,324	11,458,552	1,025.77	2,245,603	357,022	366,221,524	377,680,077	361,346	1,045.20	8.72	4,323.98	0.0119663

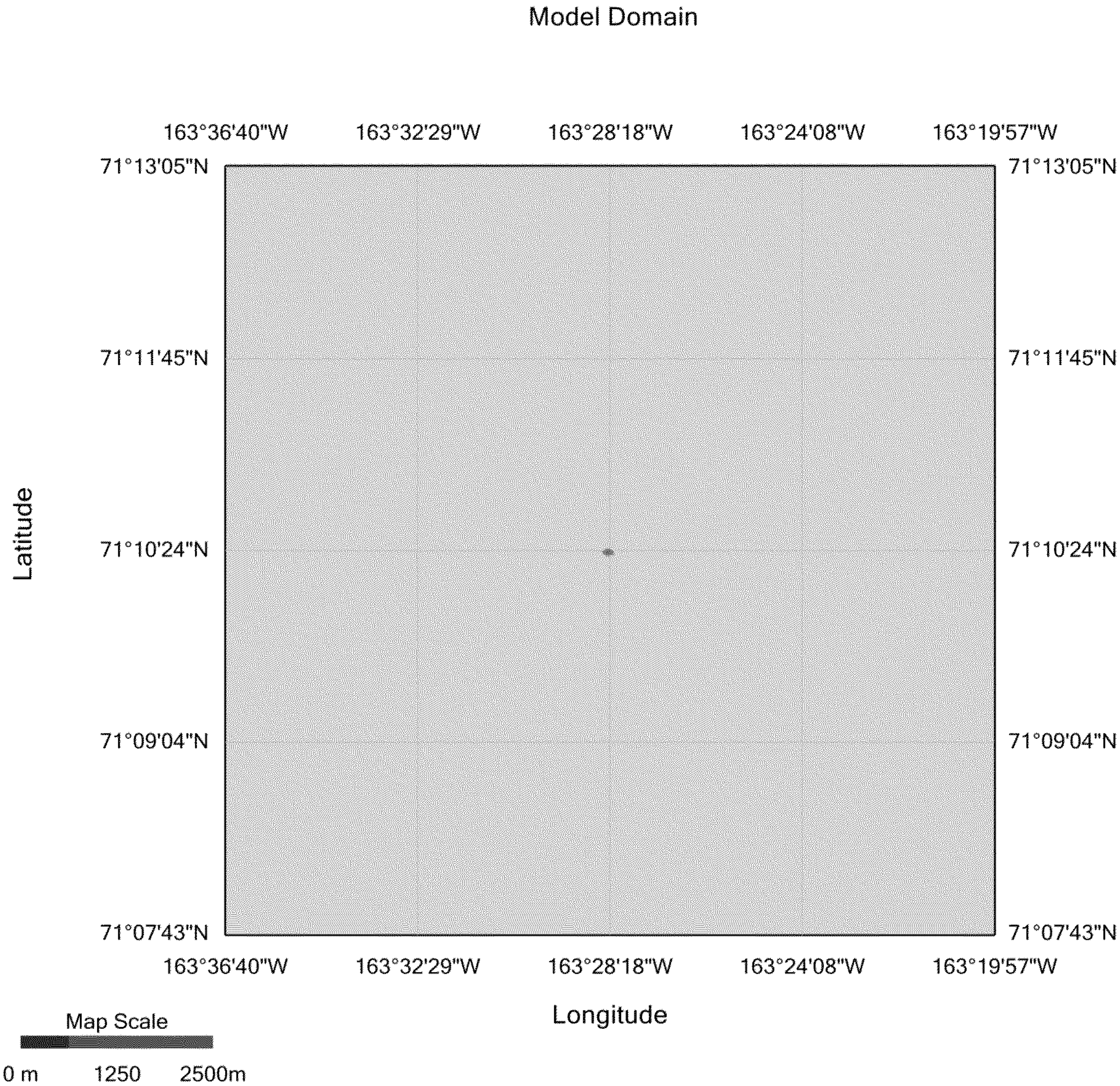
Copyright 2014 by Fluid Dynamix. Company Confidential.

SECTION 4.0 MODELING DOMAIN

The dispersion and deposition numeric simulations of the water based drill cuttings discharges for both the sea floor discharge scenarios 1 and 2 were performed using the OOC model as described in **Section 1**.

The model domain extends 5,000 m (5 km) in all directions from the discharge source. The model consists of 500 cells in the west-east direction and 500 cells in the north-south direction as well. Each cell is a 20 m × 20 m square. The well is located at the center of the modeling domain shown by a blue circle in **Figure 4-1**.

Figure 4-1: Modeling domain for the prospect well Burger J



Copyright 2014 by Fluid Dynamix. Company Confidential.

Section 5.0 Dispersion and Deposition Modeling – Mean Currents

The dispersion and deposition numeric simulations of the water based drill cuttings discharges from the drilling operations for the excavation of the MLC at the Burger J well site for the **Sea Floor Discharges (D013) at Mean Currents** scenario was performed using the OOC model. Numeric simulation was carried out for the drillings interval 01 for a drilling duration of 168.0 hours (i.e., 7 days) as presented in **Table 5-1**. A 900-second model time step (Δt) was used for the computer simulation. The OOC model predicted: trajectory and shape of the discharge plume, total suspended solids (TSS) concentrations in the water column, the total solids deposition loading, and solids deposit thickness distribution on the seabed.

Table 5-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger J

Well ID	Discharge Scenario	Drilling Intervals	Durations of Drilling (Discharge)		The OOC Numeric Model Simulation			Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate
					Total Simulation Time	Model Time Step (Δt)	Count of Total Model Steps				
			Hours	Seconds	Seconds	Seconds		m	m	(bbls/hour)	bbls/hour
Burger J	Sea Floor	01 - MLC	168.00	604,800	604,800	900	672	43.90	41.46	161.89	13,528.57

Copyright 2014 by Fluid Dynamix. Company Confidential.

5.1 Model Results for Sea Floor Discharge Scenario – MLC

The OOC model predictions for the dispersion and deposition of the water based drill cuttings in the near-field and far-field receiving water are presented in this Technical Report by the following effluent characteristics:

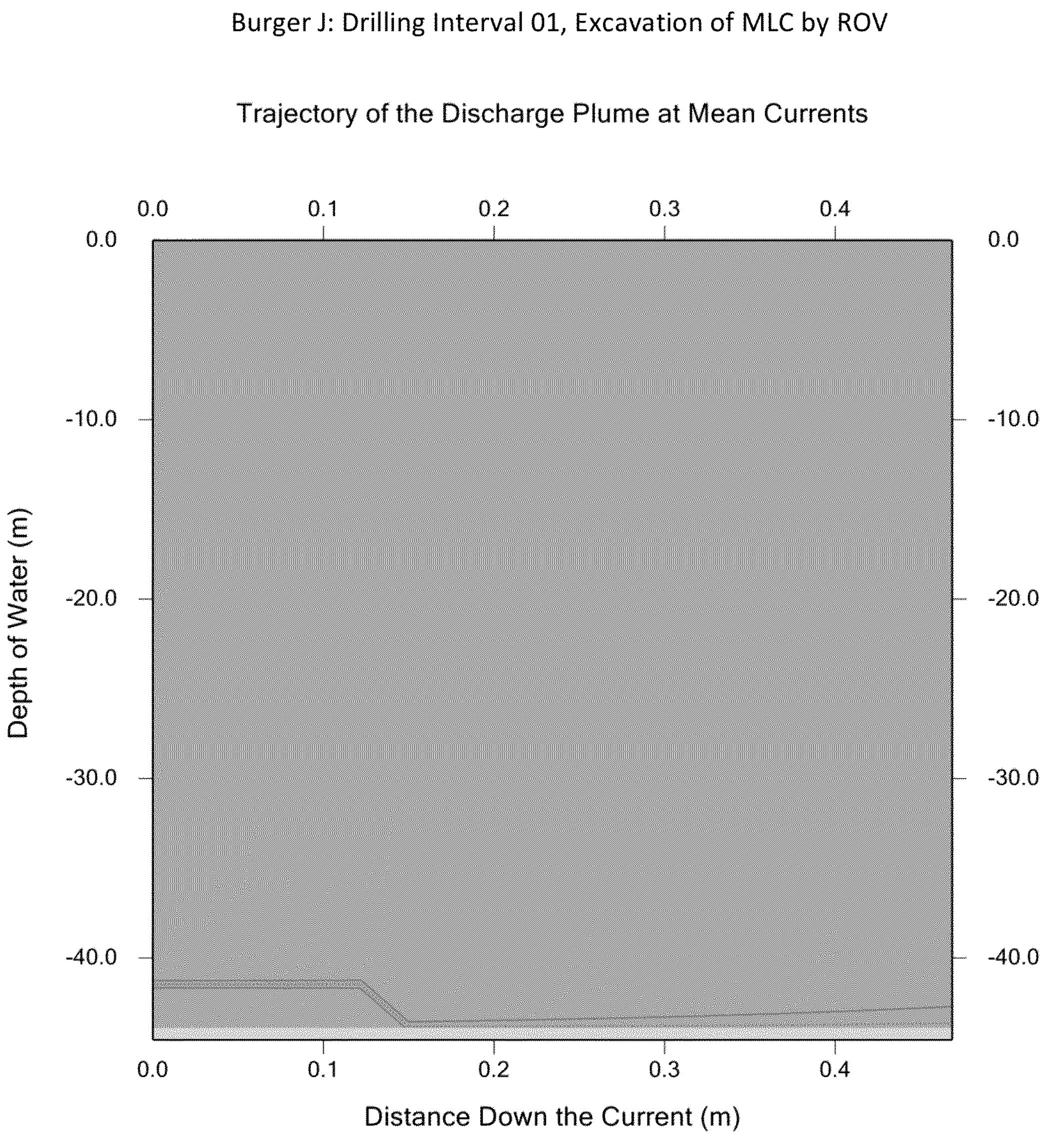
- Trajectory and shape of the discharge plume
- Total suspended solids (TSS) concentrations in the water column
- Amount of deposition (in kg/m^2) of the discharged solids on the seabed
- Spatial extent of deposition (i.e., solids thickness distribution) in centimeter (cm) of the discharged solids on the seabed

Trajectory and Shape of the Discharge Plume

The trajectory of the discharge plume is presented in **Figure 5-1**. The depth of water is **43.9** m and the discharge occurs at a depth of **41.46** m from an approximately **16.0** inches internal diameter discharge pipe of the sea floor pump at **13,528.57** bbls/hour. The discharge pipe is located at 2.44 m (or 8 feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the East. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure 5-1. It travels to the east to a distance approximately 0.45 m only from the source before collapsing onto the sea floor due to the low mean currents of 7 cm/s and the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 5-2**. The width of the plume is approximately 0.45 m at a distance 0.45 m from the source.

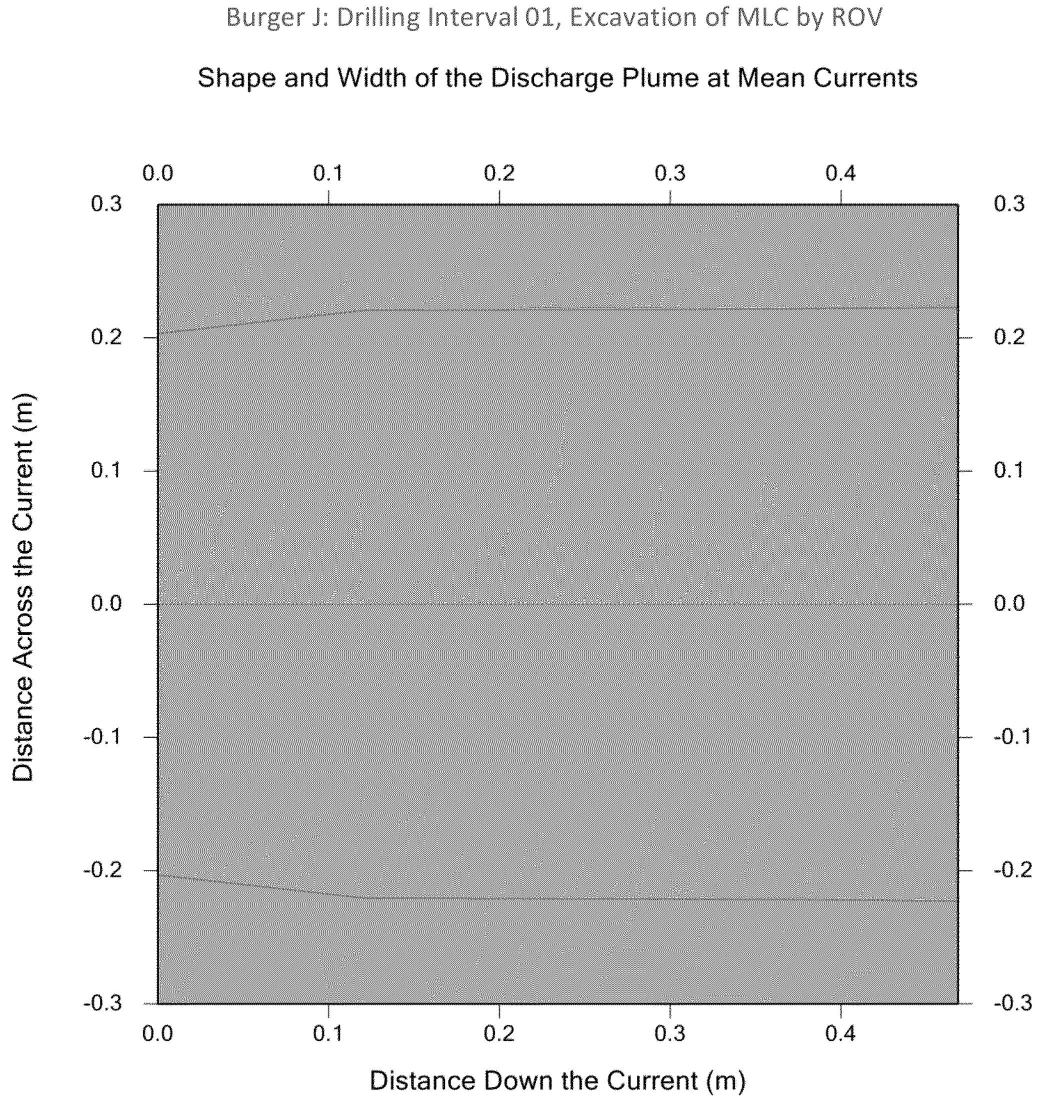
Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 5-1: Trajectory of the discharge plume, Burger J, Drilling Interval 01 - MLC



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 5-2: Shape and width of the discharge plume, Burger J, Drilling Interval 01 - MLC



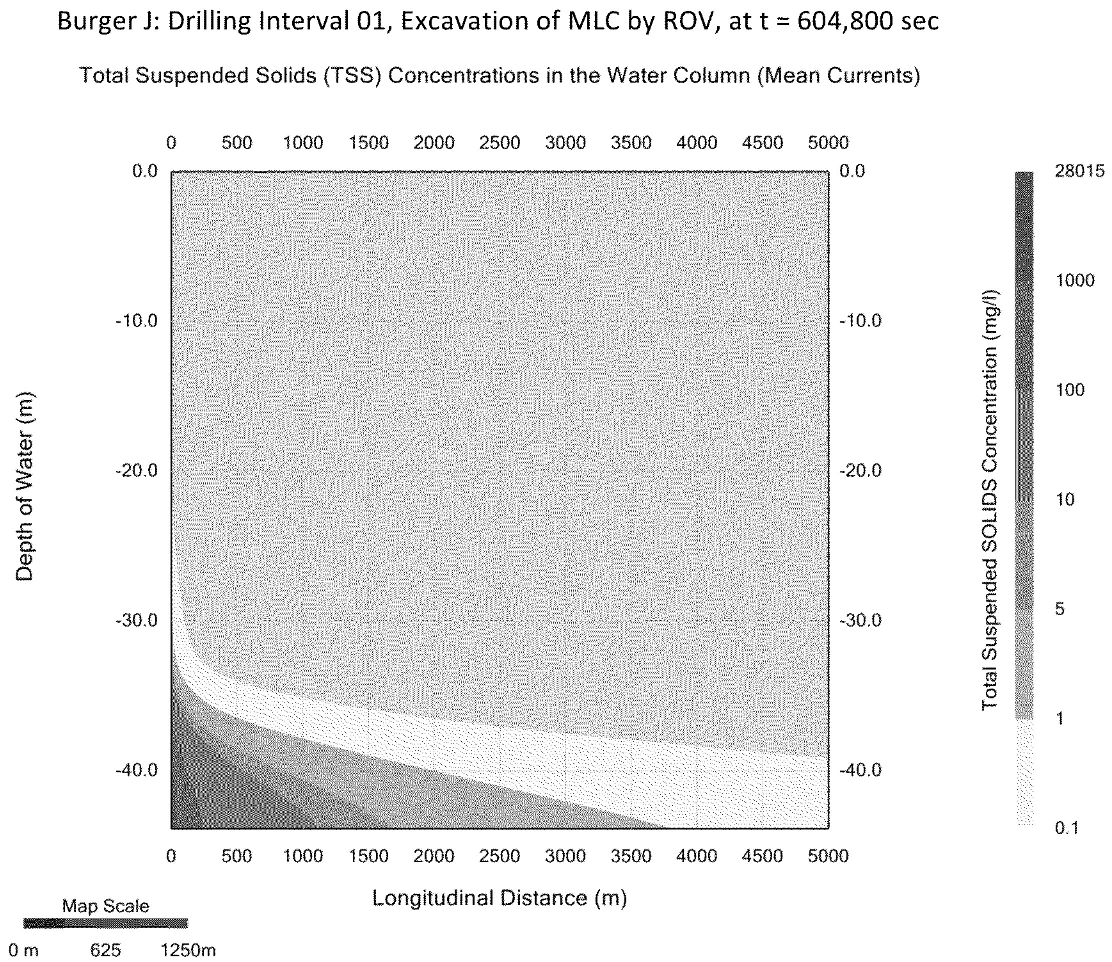
Copyright 2014 by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = 604,800 sec which is the discharge duration for this drilling interval is presented in **Figure 5-3**. The depth of water is 43.9 m at the discharge location. The maximum TSS concentration 28,015 mg/l occurs at the discharge location. It decreases to a value of 100 mg/l and 10 mg/l at distances approximately 250 m and 1,100 m, respectively from the discharge location. It varies from 10 to 5 mg/l between 1,100 and 1,700 m distances from the discharge location. It varies from 5 to 1 mg/l between 1,700 and 3,750 m distances from the discharge location. It is less than 1.0 mg/l beyond 3,750 m from the discharge location. The effect of the sea floor pump is visible in this Figure 5-3. The discharge plume is spreading farther horizontally to the east along the direction of the current than vertically. The TSS concentration is less than 5 mg/l at a depth approximately 30.0 m or less at or near the discharge location. It is less than 5.0 mg/l at a depth approximately 40.0 m at 2,000 m from the discharge location.

The TSS concentration at 100-, 300-, and 1000-m from the discharge location are: 359.1, 73.1, and 12.0 mg/l, respectively.

Figure 5-3: Total suspended solids concentrations in water column, Burger J, Drilling Interval 01

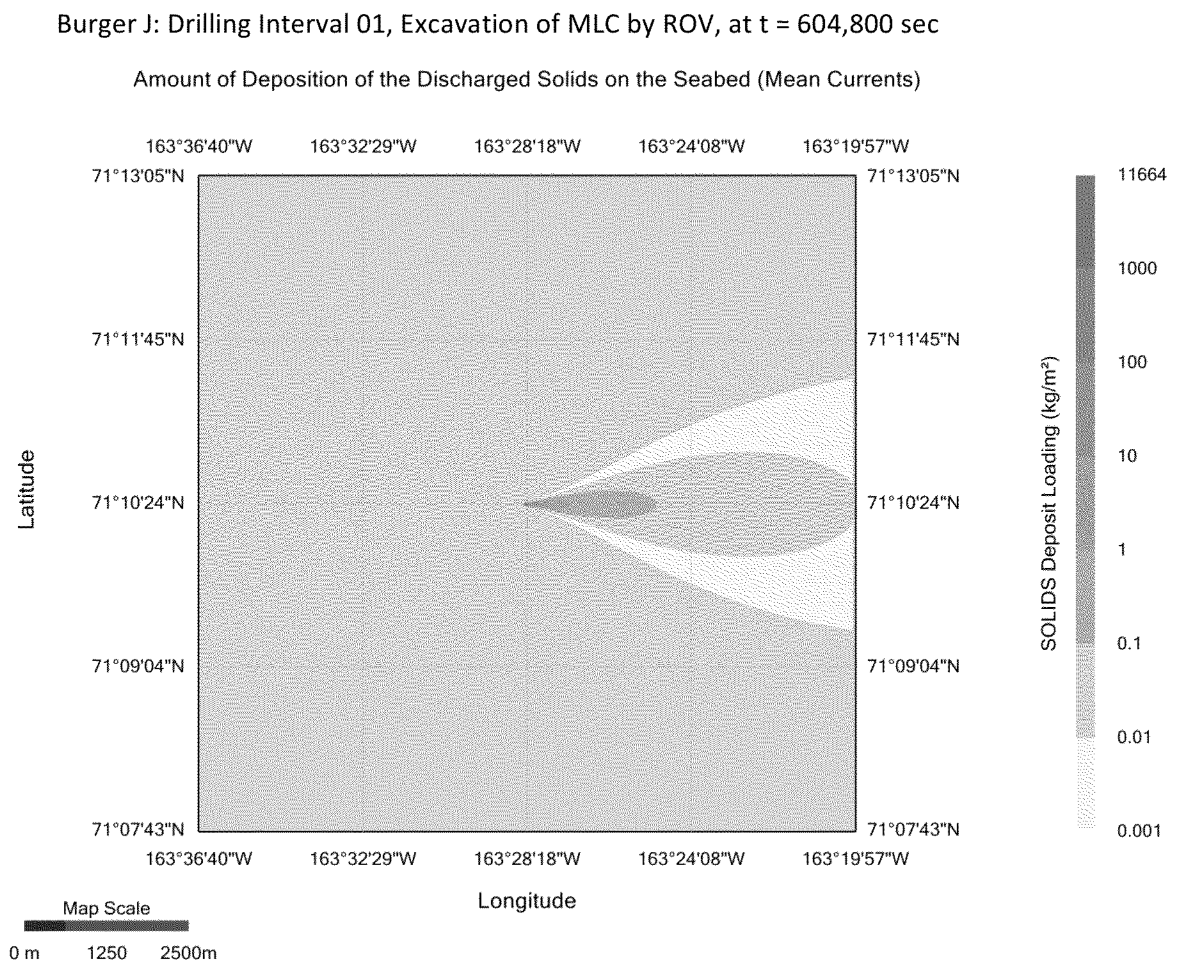


AMOUNT OF DEPOSITION (IN kg/m²) OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = 604,800 sec as a result of the discharge of the water based drill cuttings on a plan view is presented in **Figure 5-4**. The model domain extends to 5.0 kilometers (km) in all directions from the discharge location. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading 11,664 kg/m^2 occurs at 10 m to the east and 10 m to the north from the discharge location. It decreases to a value of 1 kg/m^2 and 0.1 kg/m^2 at distances approximately 700 m and 2,000 m, respectively from the discharge location. It varies from 0.1 kg/m^2 to 0.01 kg/m^2 approximately between 2,000 and 5,000 m distances from the source.

The sea floor areas affected by solids deposit loading of more than 100-, 10-, 1-, 0.1- and 0.01-kg/m^2 are: 0.345, 1.141, 7.006, 59.020, and 550.870 hectares (ha), respectively.

Figure 5-4: Amount of deposition of the solids on the seabed, Burger J, Drilling Interval 01



Copyright 2014 by Fluid Dynamix. Company Confidential.

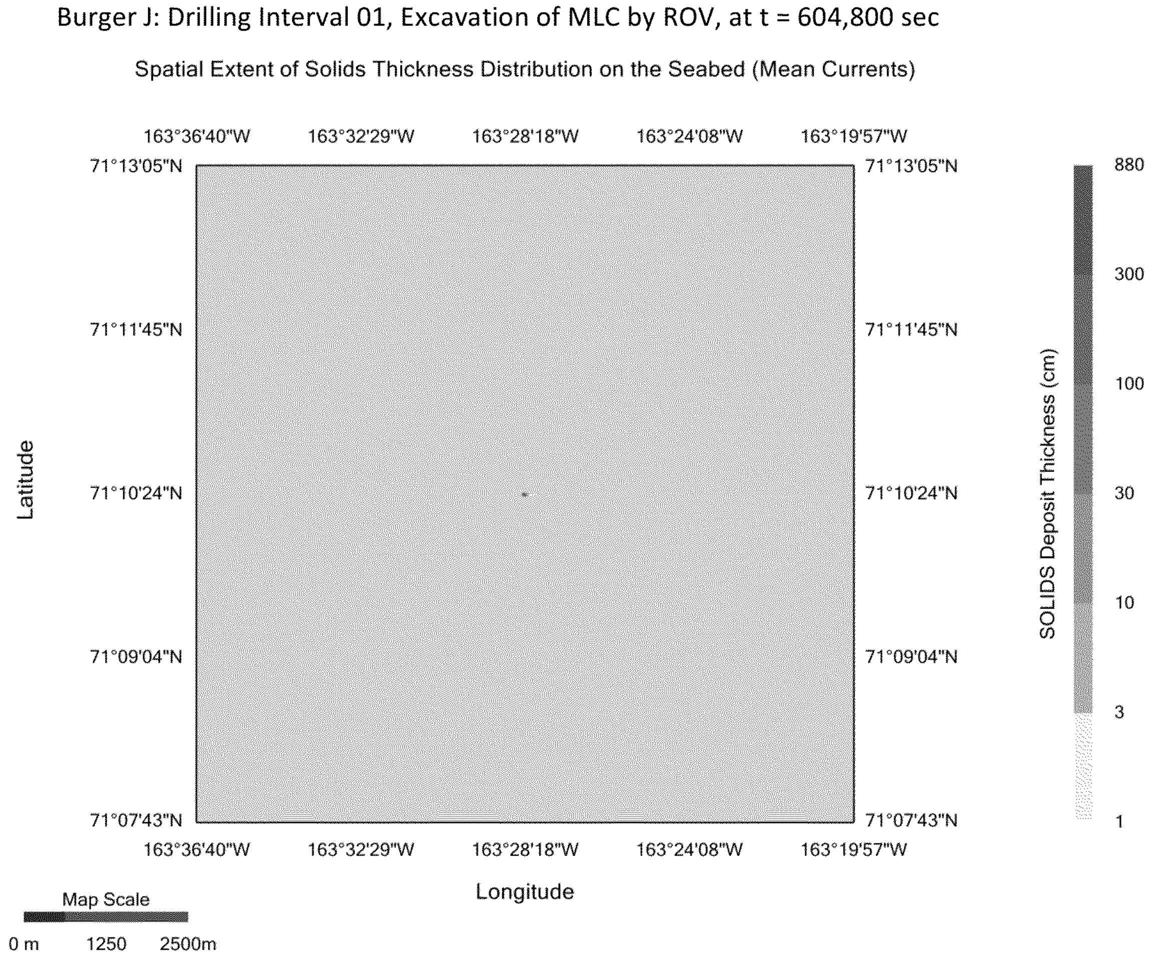
SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of 1 cm or larger deposited on the sea floor at time, t = 604,800 sec as a result of the discharge of the water based drill cuttings on a plan view is presented in **Figures 5-5a** and **5-5b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to 5.0 km in all directions from the discharge location as presented in Figure 5-5a. The solids deposited on the seabed of thickness 1 cm or larger as shown in Figure 5-5a, occurs on a very small surface area compare to the 10 km x 10 km map surface. The same results are presented in Figure 5-5b but shows only 480 m x 480 m seabed surface with the well at the center to show the details of the solids accumulation of 1 cm or larger on the seabed. The maximum deposit thickness of 880 cm occurs at 10 m to the east and 10 m to the north from the discharge location. It decreases to a value of 1 cm at a distance approximately 200 m from the discharge location.

The sea floor area affected by solids deposit thickness of 1 cm or larger is approximately a 240 m x 40 m rectangle area (or 0.981 ha to be exact) as presented in Figure 5-5b. The sea floor areas affected by deposit thickness larger than 500-, 300-, 100-, 10-, and 1-cm are: 0.099, 0.108, 0.118, 0.336, and 0.981 ha, respectively. **Figure 5-6** presents the sea floor area affected by solids deposit graphically. It shows that the sea floor area affected by solids deposit thickness of 1 cm or larger is less than 1.0 ha.

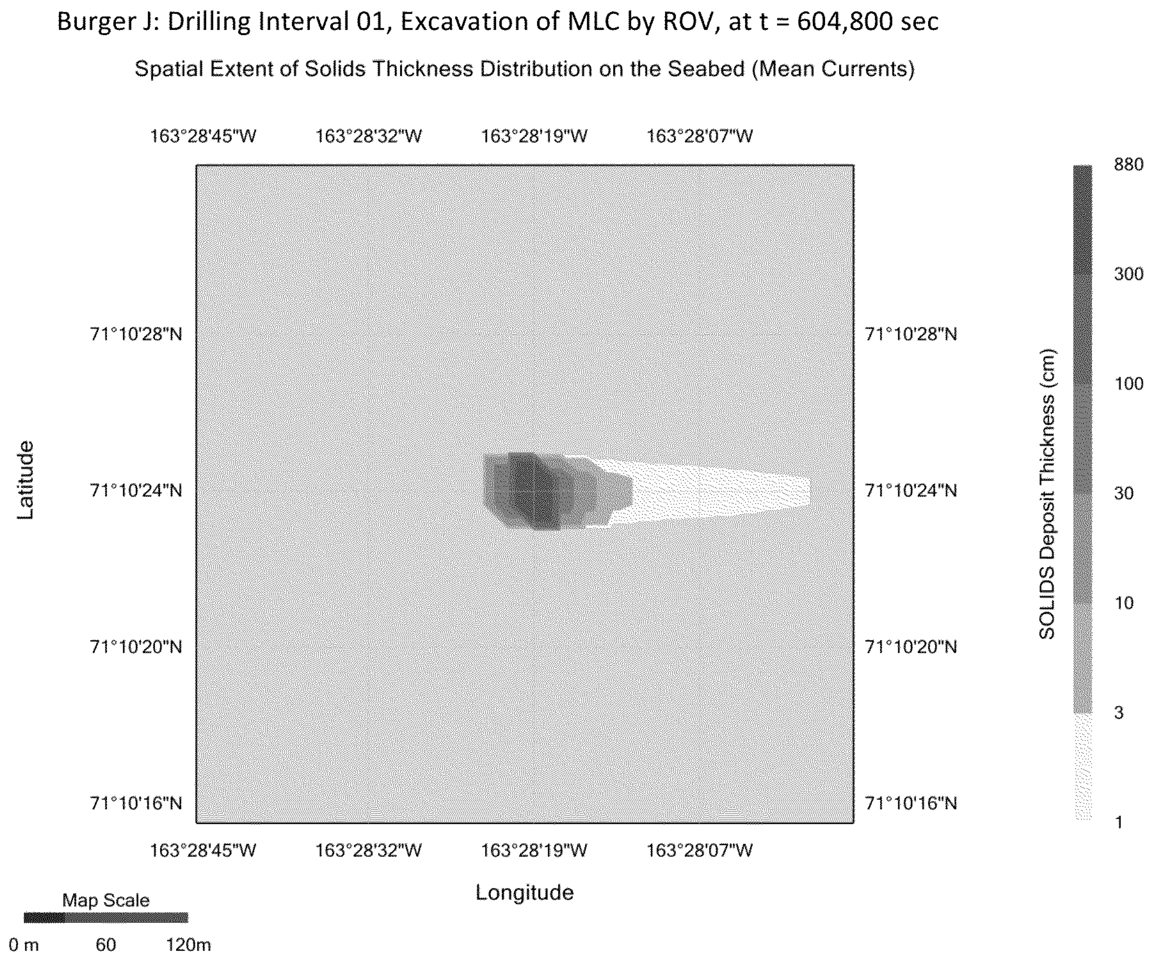
Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 5-5a: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01



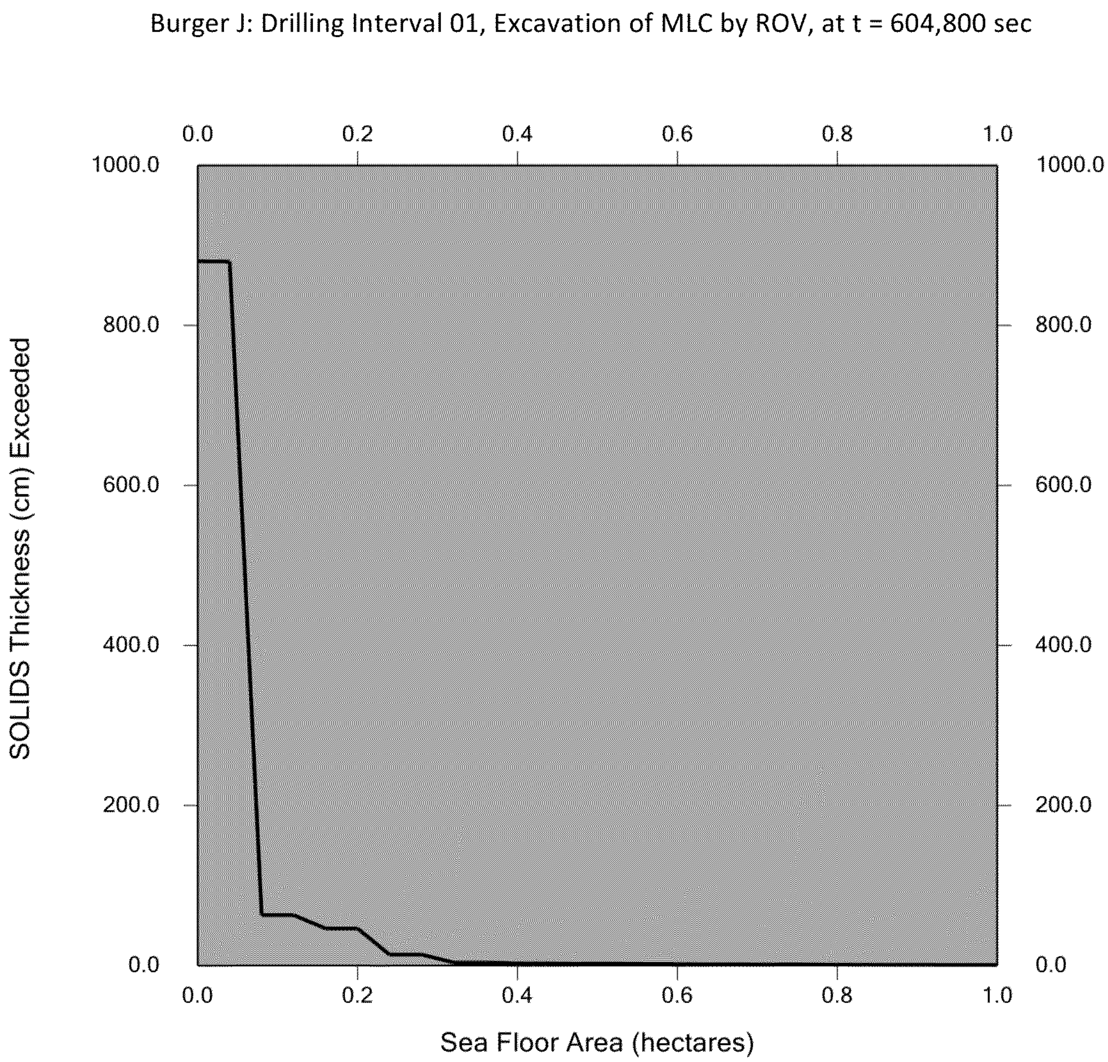
Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 5-5b: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01 (Zoom In View)



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 5-6: Sea floor area affected by solids thickness distribution, Burger J



Copyright 2014 by Fluid Dynamix. Company Confidential.

The OOC model predictions at the mean currents for the solids deposition on the seabed and the TSS concentrations from the excavation of a Mud Line Cellar (**MLC**) using a large subsea Remotely Operated Vehicle (**ROV**) for the prospect well **Burger J** located offshore Chukchi Sea are presented in **Table 5-2**.

Table 5-2: Summary Model Results - Sea Floor Discharges at Mean Currents, Burger J

The OOC Model Predictions								Mean Currents					
Well ID	Discharge Scenario	Drilling Intervals	Durations of Discharge	Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate	Solids Deposition on the Seabed			Total Suspended Solids (TSS) Concentration in Water Column - (distances from the source)		
								Area Covered by Solids Thickness (ha)		Maximum Deposit Thickness	100 m	300 m	1 km
			Hours	m	m	bbls/hour	bbls/hour	> 10 cm	> 1 cm	cm	mg/l	mg/l	mg/l
Burger J	Sea Floor	01 - MLC	168.0	43.9	41.46	161.89	13,528.57	0.336	0.981	880.3	359.13	73.11	12.03

Copyright 2014 by Fluid Dynamix. Company Confidential.

SECTION 6.0 DISPERSION AND DEPOSITION MODELING – MAXIMUM CURRENTS

The dispersion and deposition numeric simulations of the water based drill cuttings discharges from the drilling operations for the excavation of the MLC at the Burger J well site for the **Sea Floor Discharges (D013) at Maximum Currents** scenario was performed using the OOC model. Numeric simulation was carried out for the drillings interval 01 for the actual drilling duration of 168.0 hours as presented in **Table 6-1**. A 900-second model time step (Δt) was used for the computer simulation. The OOC model predicted: trajectory and shape of the discharge plume, total suspended solids (TSS) concentrations in the water column, the total solids deposition loading, and solids deposit thickness distribution on the seabed.

Table 6-1: Total Simulation Time, Model Time Step, and Discharge Rates for Burger J

Well ID	Discharge Scenario	Drilling Intervals	Durations of Drilling (Discharge)		The OOC Numeric Model Simulation			Depth of Water	Depth of Discharge	Effluent Discharge Rate	Pre-diluted Effluent Discharge Rate
					Total Simulation Time	Model Time Step (Δt)	Count of Total Model Steps				
			Hours	Seconds	Seconds	Seconds		m	m	(bbls/hour)	bbls/hour
Burger J	Sea Floor	01 - MLC	168.00	604,800	604,800	900	672	43.90	41.46	161.89	13,528.57

Copyright 2014 by Fluid Dynamix. Company Confidential.

6.1 Model Results for Sea Floor Discharge Scenario – MLC

The OOC model predictions for the dispersion and deposition of the water based drill cuttings and drilling fluids in the near-field and far-field receiving water are presented in this Technical Report by the following effluent characteristics:

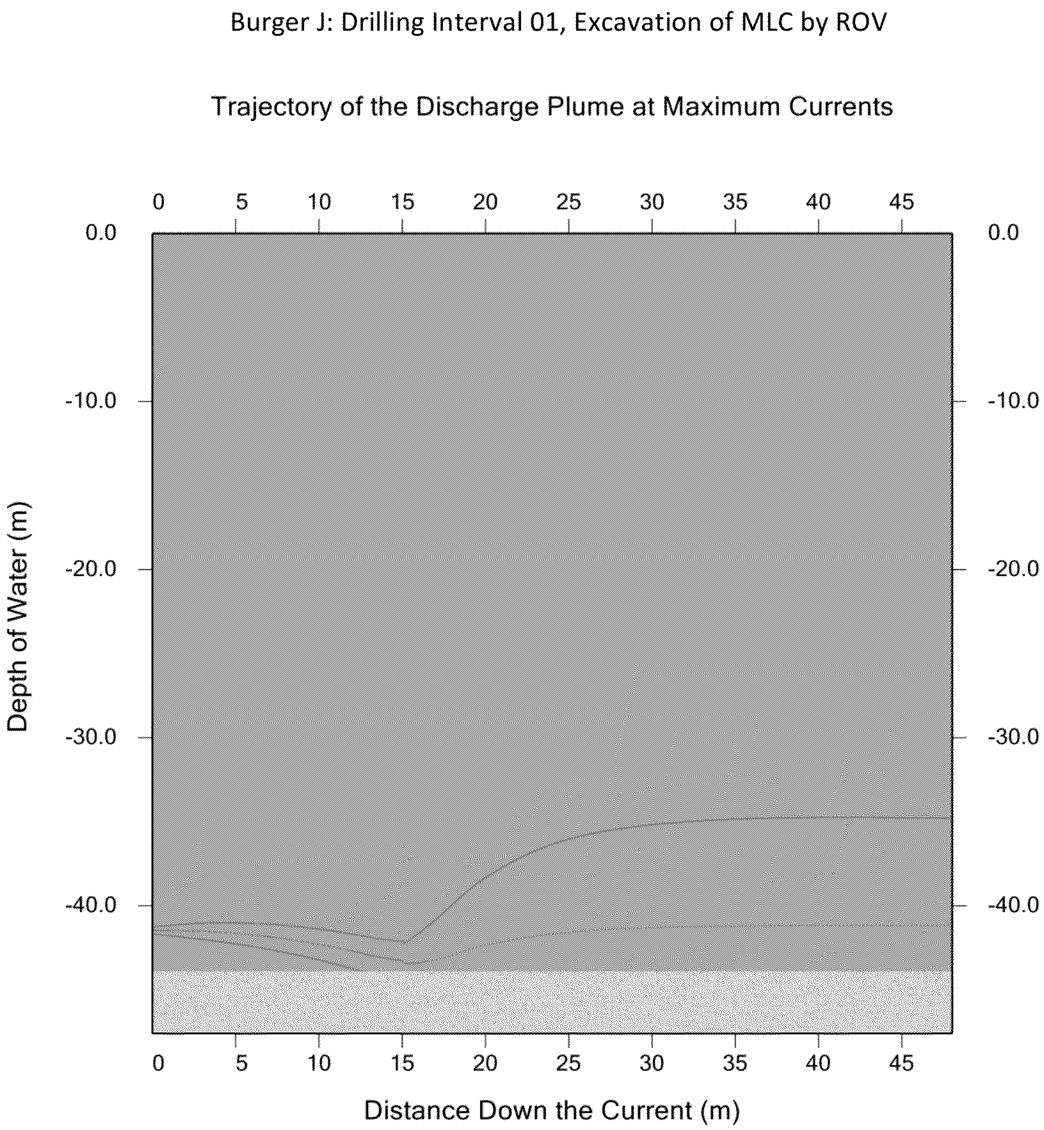
- Trajectory and shape of the discharge plume
- Total suspended solids (TSS) concentrations in the water column
- Amount of deposition in kilograms per square meter (kg/m^2) of the discharged solids on the seabed
- Spatial extent of deposition (i.e., solids thickness distribution) in centimeter (cm) of the discharged solids on the seabed

Trajectory and Shape of the Discharge Plume

The trajectory of the discharge plume is presented in **Figure 6-1**. The depth of water is **43.9** m and the discharge occurs at a depth of **41.46** m from a **16.0** inches internal diameter discharge pipe of the sea floor pump at **13,528.57** bbls/hour (or **9,470 gpm**). The discharge pipe is located at 2.44 m (or 8 feet) above the seafloor and oriented horizontally aligned with the direction of the current, which is to the East. Therefore, the heavier discharge plume attempts to shoot horizontally as seen in Figure 6-1. It travels to the east to a distance approximately 47.0 m from the source before collapsing onto the sea floor due to the high maximum currents of 25 cm/s and the proximity of the plume near the sea floor. The shape and width of the discharge plume is presented in **Figure 6-2**. The width of the plume is approximately 12.5 m at a distance 47.0 m from the source.

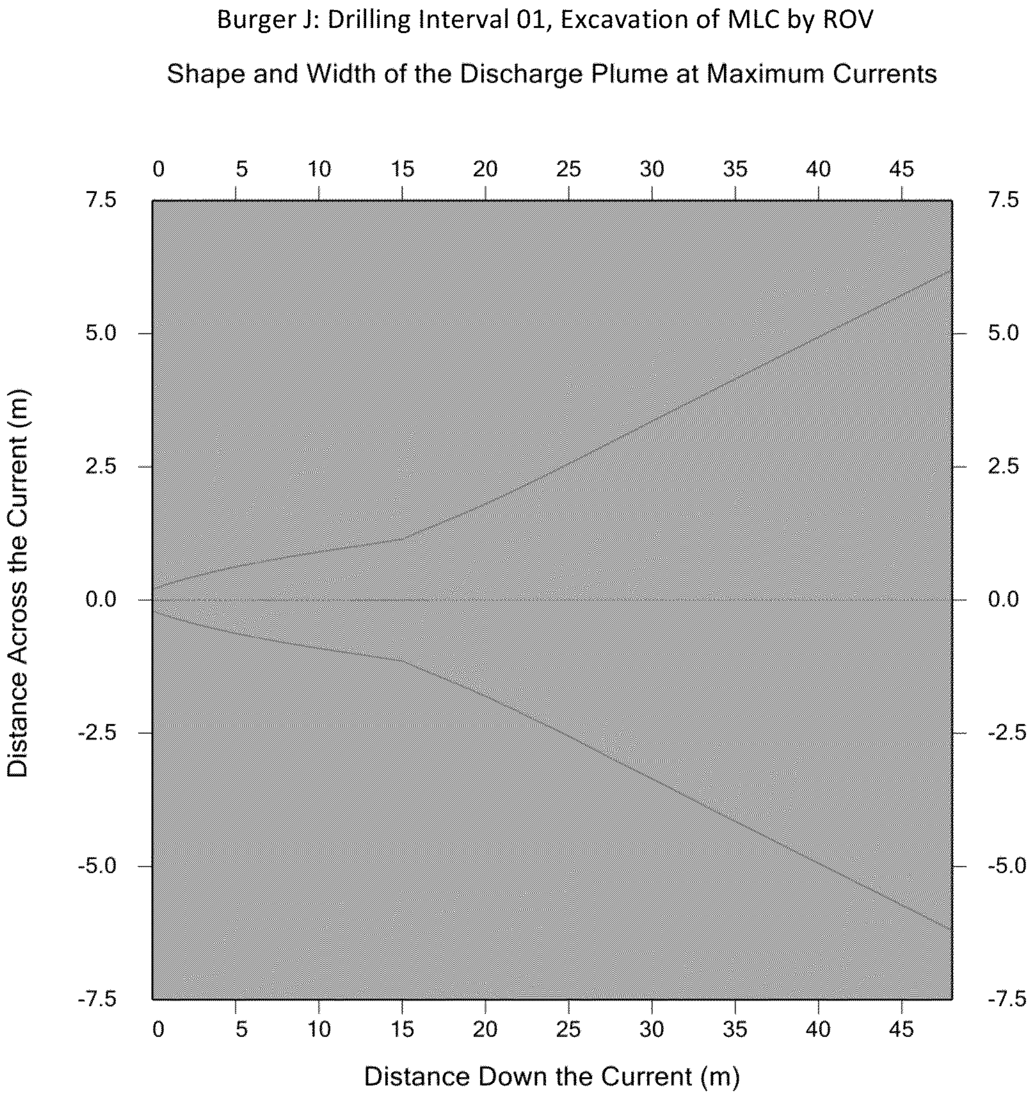
Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 6-1: Trajectory of the discharge plume, Burger J, Drilling Interval 01



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 6-2: Shape and width of the discharge plume, Burger J, Drilling Interval 01



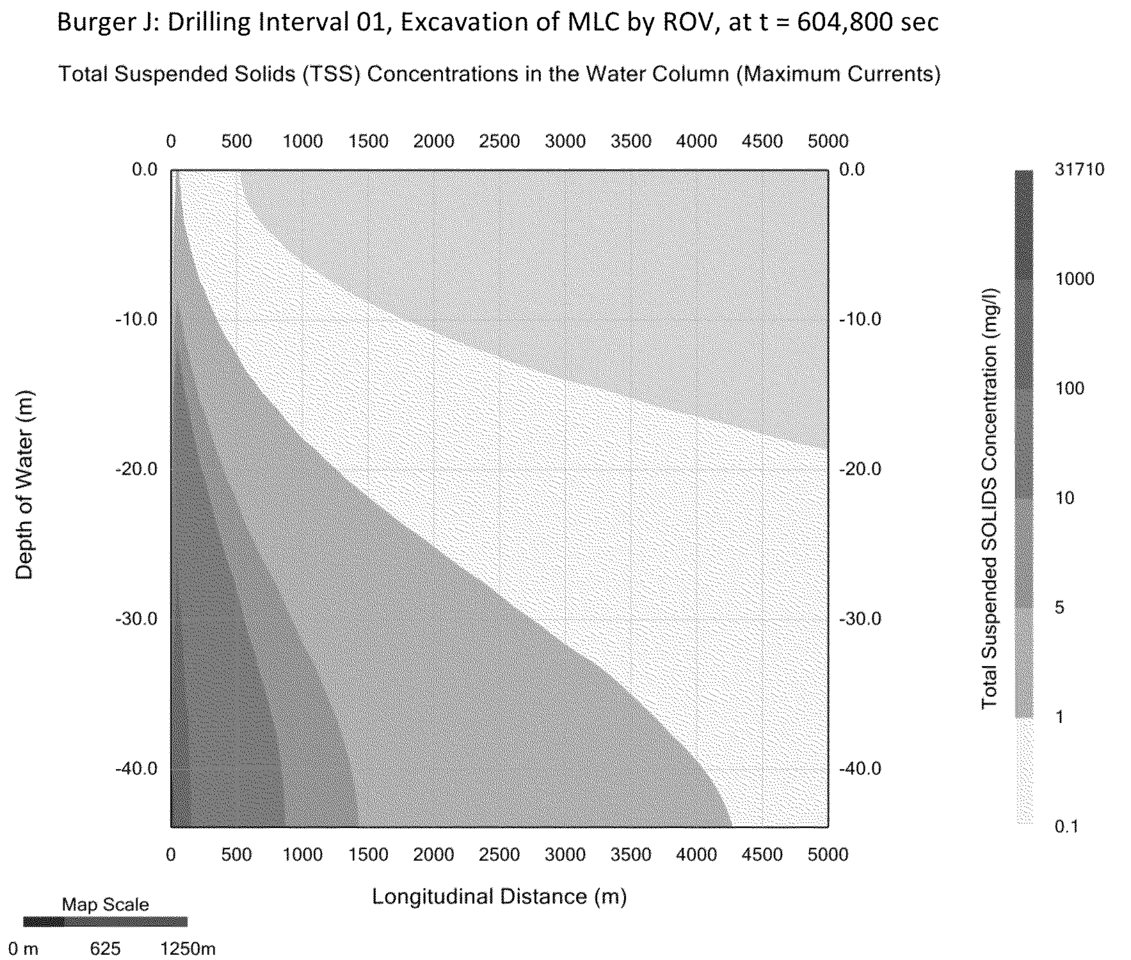
Copyright 2014 by Fluid Dynamix. Company Confidential.

TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN THE WATER COLUMN

The total suspended solids (TSS) concentrations in the water column at time, t = 604,800 sec which is the discharge duration for this drilling interval is presented in **Figure 6-3**. The depth of water is 43.9 m at the discharge location. The maximum TSS concentration 31,710 mg/l occurs at the discharge location. It decreases to a value of 100 mg/l and 10 mg/l at distances approximately 150 m and 850 m, respectively from the discharge location. It varies from 10 to 5 mg/l between 850 and 1,425 m distances from the discharge location. It varies from 5 to 1 mg/l between 1, 425 and 4,250 m distances from the discharge location. It is less than 1.0 mg/l beyond 4,250 m from the discharge location. The effect of the maximum currents speed of 25 cm/s is visible in this Figure 6-3. The discharge plume shows enhanced mixing both vertically and horizontally.

The TSS concentration at 100-, 300-, and 1000-m from the discharge location are: 161.5, 44.9, and 8.2 mg/l, respectively.

Figure 6-3: Total suspended solids concentrations in water column, Burger J, Drilling Interval 01



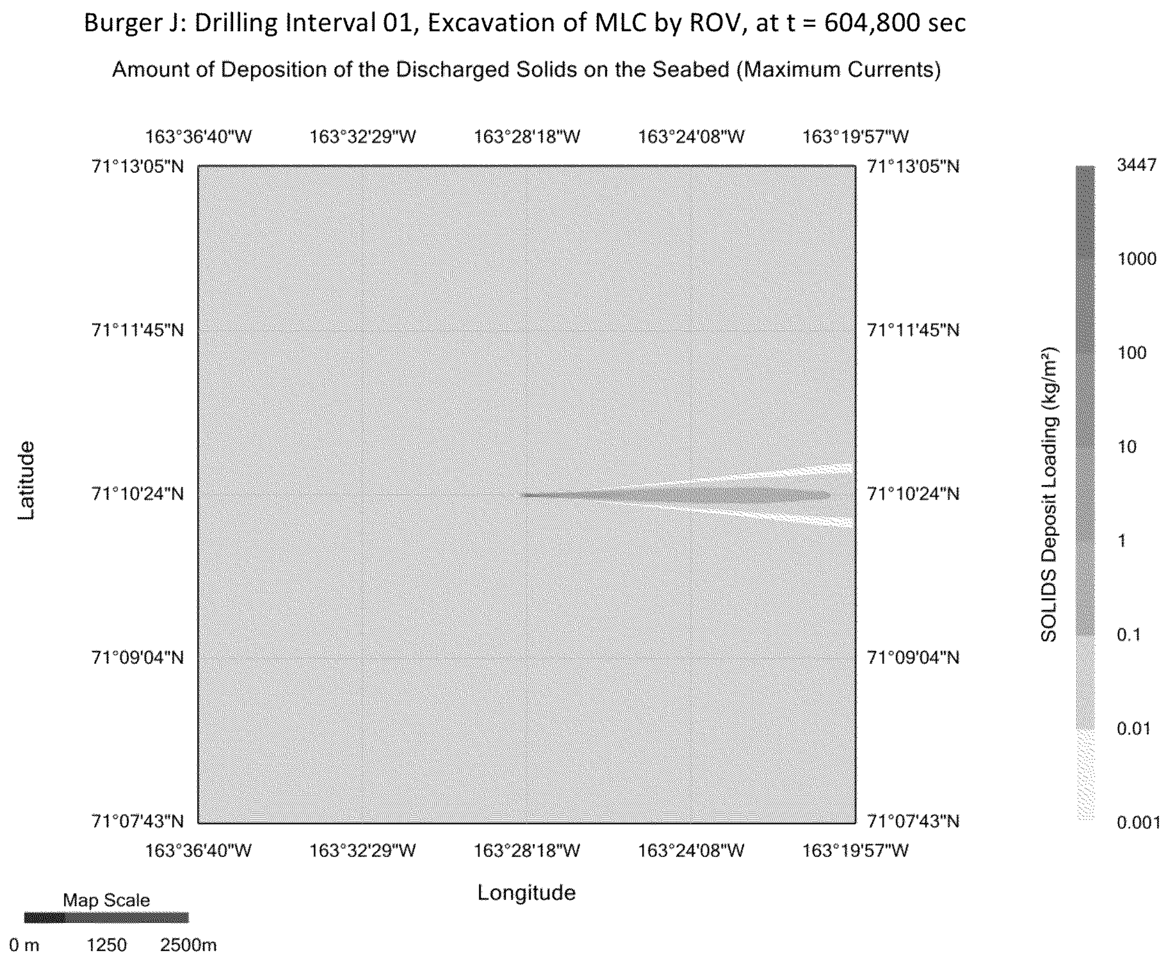
Copyright 2014 by Fluid Dynamix. Company Confidential.

AMOUNT OF DEPOSITION (IN kg/m^2) OF THE DISCHARGED SOLIDS ON THE SEABED

The spatial extent and the amount of solids loading on the sea floor at time, t = 604,800 sec as a result of the discharge of the water based drill cuttings on a plan view is presented in **Figure 6-4**. The model domain extends to 5.0 kilometers (km) in all directions from the discharge location. The map scale is located at the bottom left corner of this figure. The color bar on the right provides the range of the solids loading on the sea floor in kg/m^2 by a particular color band. The maximum loading 3,447 kg/m^2 occurs at 30 m to the east and 10 m to the north from the discharge location. It decreases to a value of 10 kg/m^2 and 1 kg/m^2 at distances approximately 550 m and 1,500 m, respectively from the discharge location. It varies from 1 kg/m^2 to 0.1 kg/m^2 between distances approximately 1,500 m and 4,500 m from the discharge location.

The sea floor areas affected by solids deposit loading of more than 100-, 10-, 1-, 0.1- and 0.01-kg/m^2 are: 0.913, 2.281, 8.283, 79.367, and 187.690 hectares (ha), respectively.

Figure 6-4: Amount of deposition of the solids on the seabed, Burger J, Drilling Interval 01



Copyright 2014 by Fluid Dynamix. Company Confidential.

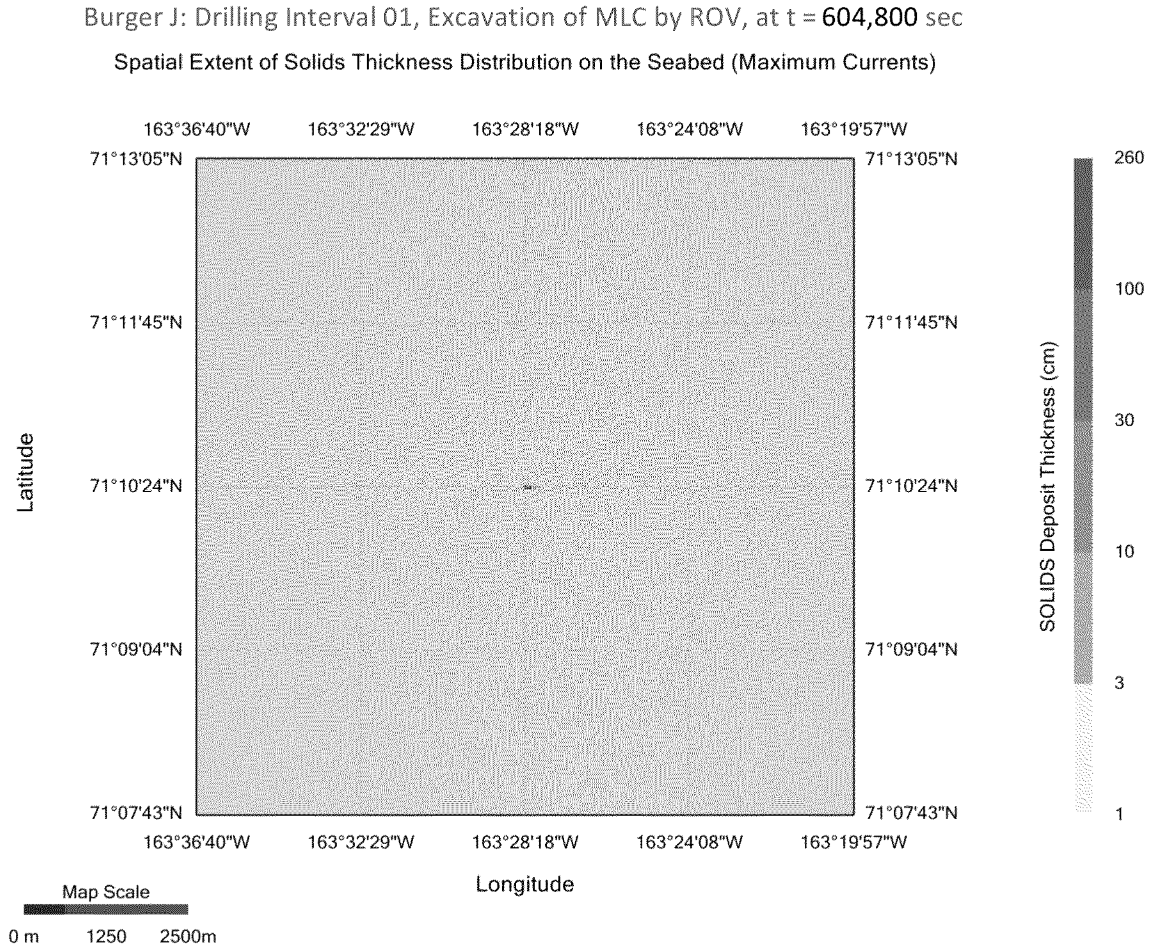
SPATIAL EXTENT OF SOLIDS THICKNESS DISTRIBUTION ON THE SEABED

The spatial extent of solids thickness of 1 cm or larger deposited on the sea floor at time, t = 604,800 sec as a result of the discharge of the water based drill cuttings on a plan view is presented in **Figures 6-5a** and **6-5b.** The map scale is located at the bottom left corner of these figures. The color bar on the right provides the range of the solids deposit thickness on the sea floor in cm by a particular color band. The model domain extends to 5.0 km in all directions from the discharge location as presented in Figure 6-5a. The solids deposited on the seabed of thickness 1 cm or larger as shown by a small dot, occurs on a very small surface area compare to the 10 km x 10 km map surface area shown in Figure 6-5a. The same results are presented in Figure 6-5b but shows only 1,040 m x 1,040 m seabed surface with the well at the center to show the details of the solids accumulation of 1 cm or larger on the seabed. The maximum deposit thickness of 260 cm occurs at 30 m to the east and 10 m to the north from the discharge location. It decreases to a value of 1 cm at a distance approximately 500 m from the discharge location.

The sea floor area affected by solids deposit thickness of 1 cm or larger is approximately a 500 m x 40 m rectangle area (or 2.003 ha to be exact) as presented in Figure 6-5b. The sea floor areas affected by deposit thickness larger than 100-, 10-, and 1-cm are: 0.270, 0.837, and 2.003 ha, respectively. **Figure 6-6** presents the sea floor area affected by solids deposit graphically. It shows that the sea floor area affected by solids deposit thickness of 1 cm or larger is approximately 2.0 ha.

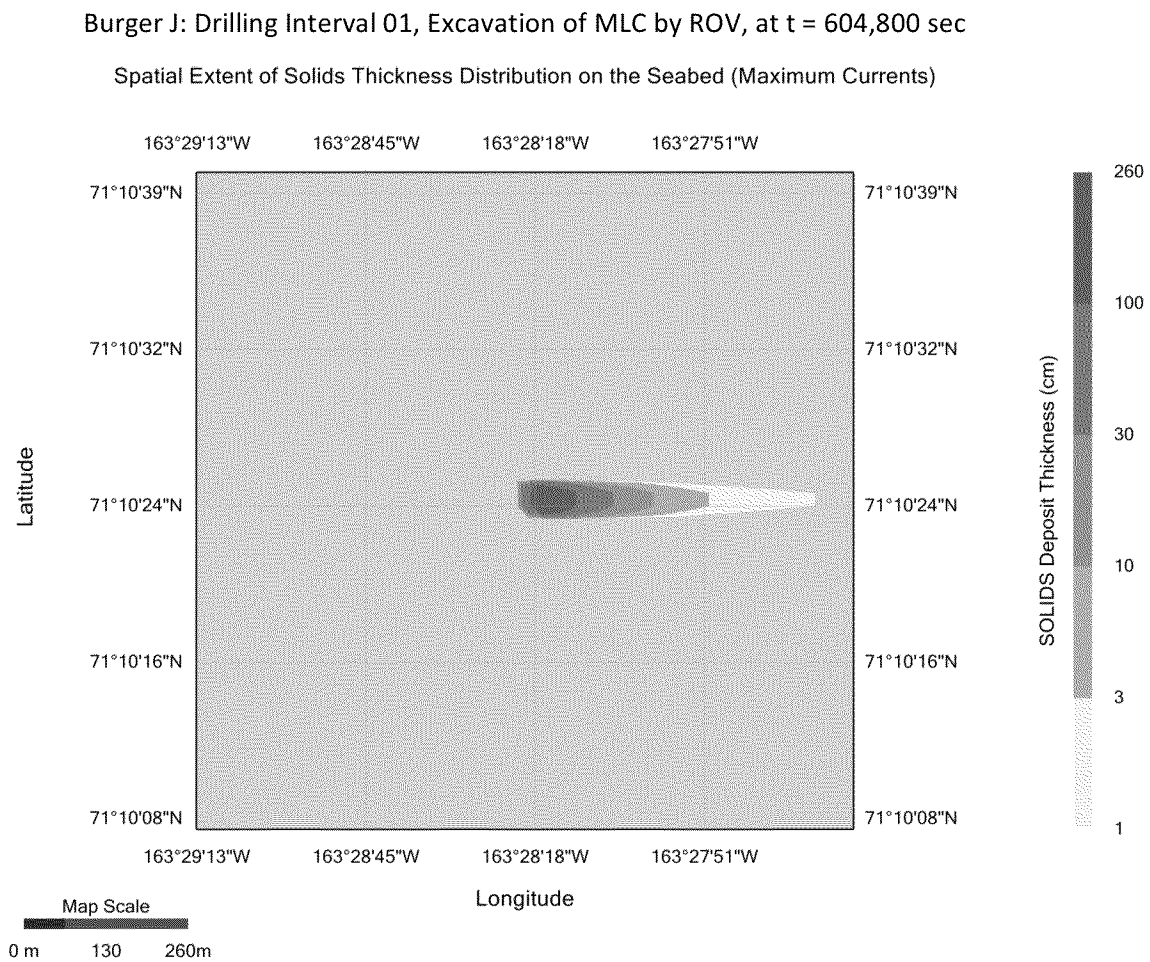
Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 6-5a: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01



Copyright 2014 by Fluid Dynamix. Company Confidential.

Figure 6-5b: Spatial extent of solids thickness distribution on seabed, Burger J, Drilling Interval 01 (Zoom In View)



Copyright 2014 by Fluid Dynamix. Company Confidential.